CHAPTER I

INTRODUCTION

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INTRODUCION

Sports are no longer just sports and games. They are business all over the world. The boom in prize money and the practice of internationally renowned sportsman signing on the dotted line to endorse the products has made sports, big business. Sports lovers all over the world are happy that reputed sportsmen are no longer obliged to follow a regime of high thinking and low living.

Today, sports have become a part and parcel of our culture. It is being influenced and does influence all our social institutions including education, economics, arts, politics, law, mass communication and even international diplomacy. In fact its scope is awesome. They attract the masses either for recreation or physical fitness or as a full time profession. The world is so advanced that Science dominates every aspect of life, sports is not an exception to it. Technology has forever changed our world, and in the process significantly increased the importance measuring and controlling performance relevant to physical, physiological and anthropometrical parameters.

The body is the temple of soul, and to reach harmony of body, mind, and spirit, the body must be physically fit. Hence where there is a sound body there we can ensure a sound mind. Research has shown that the physically fit person is able to withstand fatigue for longer periods than the unfit; that the physically fit person is better equipped to tolerate physical stress, that the physically fit person

has a stronger and more efficient heart; and that there is a relationship between good mental alertness, absence of nervous tension, and physical fitness.

1.1 PHYSICAL EDUCATION AND SPORTS

Physical Education and Sports, being an integral part of education, have also experienced the impact of scientific advancement. In present times, it is very difficult to participate in national or international competitions unless the individual chooses the right sports as per one's physical and physiological abilities and undergoes a very systematic scientific training. Physical education plays an important role to find the hidden talent at a very young age and then the talented players to attain excellent performance. Every sportsman has to be physically and physiologically fit. All major performance regardless of a person's ability is a function of the marking of these dimensions- fitness, skill, physical endowment, physiological and psychological or behavioral dimensions.

Gatchell (1976) feels that physical activity, in the form of exercise or sports participation is prudent means of enhancing health and improving the quality of one's life, while also probably preventing coronary disease. There is no scientific evidence showing harmful effects from regular exercise in a healthy person. Vigorous exercises properly adhered on a regular basis appears to have potential for adding more life to one's years and probably more years to one's life.

Herald (1972) found that regular physical activities results in an increase in the number of red corpuscles circulating in the blood. The improved O_2

carrying and waste removal capacity further increases workload capacity. Exercise can make the heart a more efficient pump, able to meet the demands of strenuous activity with fewer beats because it can pump out more blood with each contraction.

It has been seen that those who maintain a relatively high degree of fitness through the nature of their work or through physical activities suffer loss from degenerative diseases and probably live longer than those who follows a sedentary life. There is no longer doubt that the level of physical activity does play a major role in weight control. Maintaining a good calorie balance between dietary intake and energy out put requires a sound approach to both food consumption and exercise. There is some evidence to suggest that exercise has a beneficial effect on metabolic function.

Physical activities in the form of exercise or sports participation leads to lower blood pressure during moments of peak stress, to a lower level of blood fats such as cholesterol and triglycerides, which have been implicated in artery disease. It lengthens blood-clotting time and increases the endurance of the heart muscle; it also reduces excess weight and fat.

1.2. HISTORY OF BADMINTON

Badminton is a great game that every one can enjoy, regardless of size or shape. It's great for anaerobic fitness, one's reactions and the explosive power will improve. Badminton was invented long ago; a form of sport played in ancient Greece and Egypt. Badminton came from a child's game called battledore

and shuttlecock, in which two players hit a feathered shuttlecock back and forth with tiny rackets. The game was called "POONA" in India during the 18th Century, and British Army Officers stationed there took the Indian version back to England in the 1860's. The army men introduced the game to friends, but the new sport was definitely launched there at a party given in 1873 by the Duke of Beaufort at his country place, "Badminton" in Gloucestershire. During that time, the game had no name, but it was referred to as "The Game of Badminton," and, thereupon, Badminton became its official name.

Until 1887 the sport was played in England under the rules that prevailed in India. They were, from the English viewpoint, somewhat contradictory and confusing. Since a small army of badminton players had been recruited, a group formed itself into the Bath Badminton Club, standardized the rules, made the game applicable to English ideas and the basic regulations, drawn up in 1887, still guide the sport. In 1895, the Badminton Association (of England) was formed to take over the authority of the Bath Badminton Club, and the new group made rules, which now govern the game throughout the world. Badminton origin Chronicles dated to second century BC, China records a game similar to modern Badminton, and may be earliest version of the game.

Badminton quickly spread from England to the United States, Canada, Australia and New Zealand, and made big strides in Europe. Although men first played it, women became enthusiastic about it, and interest now is about equally divided. The first All-England championship for men was held in 1899 and in 1900 the pioneer tournament for women was arranged. These, however, were

regarded as "unofficial" and 1904 marked the beginning of the official All-England matches. The growth of badminton's popularity in the British Isles is evidenced by the fact that in 1920 there were 300 badminton clubs in England, about 500 in 1930, and over 9,000 in the British Isles soon after the World War II.

In 1934, the International Badminton Federation (IBF) was organized with nine members - Canada, Denmark, England, France, Ireland, Netherlands, New Zealand, Scotland and Wales. Membership grew steadily year after year. It became the sport's sole international governing body in 1981. The International Badminton Federation (IBF) decided in March 1939, that the time had arrived for the inauguration of international competition. Its president, Sir George A. Thomas, Baronet, offered a trophy for the winning team. The war and post-war shortages of shuttlecocks delayed the first Thomas Cup matches until the 1948-49 season. The idea of a women's international team badminton championship along the lines of the Thomas Cup was broached in 1950. It was turned down then because of financial problems. The topic continued to be brought up and eventually it was decided to establish the tournament on a triennial basis. Mrs. H. S. Uber of England donated the trophy, which is called the Uber Cup. The first tournament was held during the 1956-57 season. Since then, the number of world events has increased to seven, with the addition of the Uber Cup (ladies' team), World Championships, Sudirman Cup (mixed team), World Juniors, World Grand Prix Finals and the World Cup. Badminton was first contested as an official Olympic sport at the 1992 Olympic games in Barcelona, Spain.

1.2.1 **BADMINTON TODAY**

Badminton is a game that somewhat resembles tennis and volleyball and involves the use of a net, lightweight rackets, and a shuttlecock, a cork ball fitted with stabilizing feathers. Two or four players play it, either indoors or outdoors, on a marked-out area 44 ft (13.41 m) long by 17 ft (5.18 m) wide for the two-player game and 20 ft (6.10 m) wide for the four-player game. A net is fixed across the middle of the court, with the top edge of the net set to a height of 5 ft (1.52 m) from the ground at the center and 5 ft 1 in (1.55 m) at the posts. The players hit the shuttlecock back and forth over the net with the rackets.

Recently there have been lot of changes is made regarding the scoring system to be adopted starting from 3x15 points, best of three games for men and 3x11 points, best of three games for women. Later the scoring system was experimented to 5x9 points, best of five games and then to 5x7 best of five games but nothing was materialized, finally today it is rally scoring system of 3x21 points, best of three games, which can be extended up to a maximum of 30 points. These changes require different types of Physical, Physiological and Psychological preparation for the players as the speed of the game has changed along with it from the start of the first service and rally it is challenging. After implementation of Rally system in Badminton, two equal potential players while playing in a competition, the player with positive thinking since the start of the game with less negative errors will win the game.

1.3. BADMINTON SKILLS

Badminton occupies a significant place among sports. It is a game of masterful skills and deception, anticipation and concentration. It is an energetic game giving enjoyment and pleasure while it demands fitness and dedication. It requires physical and mental attributes to be in the top gear to tackle all eventualities in the match. The match is won by a perfect amalgam of physical condition ,mental attitudes to be in the top gear to tackle three game match, a player will run about a mile, make 350 sharp direction changes, and hit the shuttle 400 times. If a badminton match lasted for 45 minutes (average time), the shuttle would be in flight for approximately 20 minutes. By contrast a 60 minute Foot Ball game boils down to only about 14 minutes to play. A Badminton player operates at 140-150 heartbeats per minute during the game, the count going up to 180 and above in a fast rally. The player should recover in a maximum of ten seconds and has to continue at such a level throughout the match, which may be anywhere between half an hour to one hour or even more.

To perform creditably, a player must possess speed, strength, cardio – vascular endurance, agility, faster flexibility and reaction time etcetera. There is therefore no doubt that the physical and physiological variables should be woven together to enhance performances at world level. Even though certain physical and physiological variables have been discussed and reviewed in their relationship to performance in Badminton, it still remains to be established scientifically. Therefore, the present study was undertaken with a view to make generalizations in regard to Physiological ,Physical and Anthropometrical

parameters as close association with the playing ability of elite Badminton players.

Broadly speaking badminton training is similar to conditioning for the other racket sports such as Tennis and Squash. A simple movement analysis however, reveals a few key differences that will affect the competitive Badminton player's training regimen. Many shots in Badminton are played overhead – more so than Tennis or Squash for example. Badminton players also rely much more on the wrist flexors for generating power compared to Tennis players. While this may not lead to a vastly different training program, exercise selection and the percentage of time dedicated to some exercises over others will change. The average rally length at an elite Badminton level is 6-8 seconds and is interspersed with rest periods of about 15 seconds .Individual rallies would place a high demand on the anaerobic, a lactic energy system with several back-to-back rallies relying on recovery of the creatine phosphate pool . As a Badminton match lasts at least 45 minutes, short, intense periods of activity are underpinned by aerobic endurance. Clearly speed and agility play a crucial role, and lateral movements are called upon to even greater extent than in Tennis. Finally, strength and explosive power conditioning should form a fundamental part of a Badminton training program – necessary to maximize speed about the court and powerful overhead smashes.

To play well, a badminton player need to improve his skills, mostly in the form of different strokes.

1.3.1 STROKES

1.3.1 Strokes Production

Stroking technique may be defined as a system of sequential and simultaneous movements that enable the player to win a rally by hitting the shuttle over the net to the ground on the opponent's court. There is general agreement among top players and coaches that modern badminton is a very fast game where "speed is the key link" , and "both technical and tactical training must meet the requirements of speed, aggressiveness, accuracy and flexibility "(Yangren Shui, 1978).

As far as technique of stroke production is concerned the major performance criteria are speed, accuracy and consistency. Among these factors, consistency is result of regular, intensive and intelligent practice, the aim of which is to provide an automatic movement which can be adjusted to quickly changing situations. Speed and accuracy are highly dependent on the player's ability to fully utilize the body's anatomical and physiological properties as well as basic physical laws. In addition, speed of movement is also dependent on neuromuscular coordinative abilities that can be improved by intelligent and complex training routines.

1.3.2 Anatomical Background

The articulations of the joints of wrist, elbow and shoulder are involved in all strokes. Already at this point it must be emphasized that most movements also involve the joints and muscles of the trunk and the legs.

The contribution of the joints involved in a particular stroke may slightly vary among different players, With the aid of high speed cinematography it has been established, however, that the wrist plays only a minor role during power strokes of smash and clear. In their detailed biomechanical study of the fore hand and back hand smash, the Canadiens Gowitzke and Waddell came to the conclusion that "in both strokes"the players showed little or no 'classical' wrist movement and adopted a wrist position throughout most of the stroke best described as radial flexion"(Gowitzke and Waddell, 1978) . In power strokes the main source of power supplied by the arm has been identified as inward and outward rotation of the upper arm, and pronation or supination of the forearm.

1.3.3 Physiological and Biomechanical Background

In order to accelerate a racket which weighs only around 100 grams, a player needs explosive power, not brute strength. The athlete must generate maximum force in the shortest possible time. According to one study the approximate time it takes a player to execute a power stroke is one tenth of a second.

The task of the badminton player is facilitated by the rebound effect; a muscle develops more power and consumes less energy if it is stretched immediately before being activated (Astrand and Rodahl, 1977) .. This effect may be observed in many situations, especially during throwing and hitting type actions.

The common feature of movements incorporating the rebound effect is a distinct sequence of joint actions. "The sequence of joints acting in the power strokes is initiated by the larger, more proximal muscles of the body and proceeds toward the smaller, more distally located muscles" (Gowitzke and Weddell (1978). If we move the hip(i.e. the proximal joint) ahead of the shoulder (the distal segment), the abdominal muscles(the agonists are stretched, they store elastic energy which "can support the chemically yielded energy during the contraction"(Astrand and Rodhal, 1977).

The advantages of employing sequential joint actions during power strokes are the muscles are stretched before contraction and develop more power. The forces of inertia existing at the beginning of the movement can be easier overcome by activating the large and powerful leg and trunk muscles.

1.3.4 Main Phases of a Stroke

According to conventional wisdom a badminton stroke consists of back swing, forward swing and follow through. The following descriptions of a javelin throw fits very well for the power stroke in badminton:" while the force producing phase of the trunk has already started, the arm is still in the preparatory phase; while the main phase of the upper arm has already begun in the shoulder joint, the elbow is being flexed in order to prepare the final arm extension"(Meinel, 1977) .

The coach should rather concentrate his attention on the positions and movements of the major joints, since their sequential actions during preparations, hitting phase and recovery determine both the speed and accuracy of the stroke.

The joints of ankles, knees, hips, shoulders and elbows of their articulations, their positions of movements during the three phases of the action are termed key elements of the stroke. Among the key elements the hip joint deserves special attention. It plays a central role during all movements which involve the trunk; during preparation the hip joint is usually bent. If possible, it should be straightened in the hitting phase. The left arm , which should be bent at the elbow, also plays an important part, if it is moving in coordination with the right arm. it may be used for balancing purposes during lunges and jumps and facilitates trunk rotation.

1.3.5 Analysis of Forehand Over Head Stroke

Preparation

It is assumed that the player has taken up the ready position, or is already travelling to the rear court, in other words, the players body is square to the net. The preparation begins with the player's body rotating backward by a quarter turn, (i.e. by 90 degrees). At the end of this trunk rotation both hip and shoulder axes are at right angle to the net, the right knee and foot tip are pointing to the sidelines. The right foot carries the body weight and must be placed fully and firmly on the floor in order to secure a base for the push-off. The joints of both legs (ankles, knees, hips) are well bent.

At the same time the shoulder axis must be tilted so that the right shoulder is discernibly below the left one; The right elbow pointing toward the floor and well bent; thereby the right hand remains close to the body at about shoulder level. During preparation, many players do not bend their right elbow sufficiently and carry the hand away from the body and well below shoulder level.

During the hitting phase, however, the hand must be raised to enable the racket head to be dropped down across the left shoulder. A delay in raising the hand can cause problems if the shuttle is approaching quickly; a player who has developed the habit of carrying the hand well below the shoulder might not be able to hit the shuttle overhead. A player has to quickly move the right hand up to the shoulder right at the start of the preparatory phase. The wrist is straight or slightly tilted toward the thumb (i.e. radial flexion).

Stance for Forehand Stroke

The body should be turned to sideways, the left foot pointing to the opponent court and the right foot facing to the side lines just right angles to the left foot. At the same time the left arm to be raised until the elbow points toward the approaching shuttle, the left thumb should point towards the baseline.

A triangle (or trapezoid) has now been formed, the lowest point of which in space is the right elbow. "One side (of this triangle) is formed by the racket and the right forearm, the other by the left forearm. The basis of the triangle is formed

by the shoulder axis and runs from the right elbow through the shoulder axis to the left elbow" (Niesner and Ranzmayer 1980)

1.3.6 Hitting Phases

During over head strokes the hitting phase may be further divided in three subsidiary phases which correspond to the serial contractions of the muscles in legs, trunks and arms.

First Subsidiary Phase

This phase starts with a push- off from the right foot effected by straightening the leg joints. There must not be any pause between the preparatory bending of the leg joints and the push-off (rebound effect). If the player was able to get behind the shuttle(which is dropping down in front of the athlete), the body weight is transferred to the left (forward) foot. An alternative frequently used by Asian players is to jump upward to the approaching shuttle. If the shuttle is about to pass the player, he or she must jump backward. In all three situations the push-off must be followed by a forward rotation of the right leg and hip.

The key actions during this phase are leg extension, forward rotation and extension of the right hip. The right shoulder is still kept back; in this way the abdominal muscles, which are operative in sub-phase two, are put on stretch.

Second Subsidiary Phase

The second subsidiary phase begins with the player raising the right shoulder, while simultaneously lowering the left one. The elbows exchange their respective positions in space: while the left elbow moves downward, the right one is raised upward.

While the trunk is already in its main phase the system 'arm - racket' is still in the preparatory phase. At the start of the shoulders' tilting movement a radial / dorsal flexion of the wrist takes place, accompanied by forearm supination and upper arm outward rotation . This causes the racket head to describe the first part of the loop, during which it is "moving over the left shoulder blade across the back toward the right body side"(Ranzmayer,p.200) : At this point the trunk is arched backward, the muscles of the chest, shoulder and right arm are put on stretch.

When the right elbow is at shoulder level (or slightly higher) the shoulder axis is rotated forward; it now performs a tuning tilting movement. Viewed from behind, the triangle's base remains intact, since both upper arms and the shoulder axis still form a (more or less) straight line; the distance between the elbows remains roughly the same. At this point it is well to stress the important role played by the left arm, during both preparation and hitting phase the player should be encouraged to consciously use the left arm in order to assist the tilting movement of the shoulders and trunk rotation.

Third Subsidiary Phase

The right upper arm continues its upward/ forward movement until the elbow joint is being extended. Shortly before contact this movement is followed by upper arm inward rotation, forearm pronation and wrist extension. Frequently, however , throughout the action the wrist is held in a position of dorsi flexion and radial flexion and little movement is observed. "By these actions the racket head is accelerated along a semicircle which is nothing else than the acceleration phase of the loop.

Recovery

The racket head, after contact, proceeds forward and downward. In power strokes it is positioned directly under the hand with the shaft vertical. At this point the face of the racquet is perpendicular to the floor, i,e 'on edge' when viewed from the front, The racquet reached this position following contact with the shuttle by continuing elbow flexion, maximal pronation of the fore arm radial flexion of the wrist. The follow throw is terminated by a elbow the racket is brought back to the ready position.

Strokes are being applied in every skills of badminton. The descriptions of badminton skills are presented below:

1.3.7 Service

A service is delivered as soon as the shuttle contacts the racket. At the moment of contact the shuttle must be below the server's waist (considered to be the upper edge of the hip bone or more generally designated as the belt line) and the head of the racket must be higher than any part of the hand holding the racket.

1.3.8 Serving stance

The important thing is to be relaxed when serving, assume a stance near the center serving line approximately three feet behind the short service line, since the service is normally a fore hand stroke, the left foot is ahead of right foot. In order to simplify the delivery, place the racket back, wrist slightly cocked back, so that it is ready for the forward swing. Hold the shuttle between the forefinger and thumb of one's left hand and comfortably extend one's arm out at a shoulder height so that one can drop the shuttle well ahead of his body in line with his right foot. This will give his racket a free passage for the swing forward to meet the shuttle.

Body weight at the end of the prepared back swing, should be leaning slightly over his back foot. Crucial part of the serve, the forward swing while begins, drop the shuttle, and do not toss it. Just open the forefinger and thumb and let the shuttle drop straight down. This simple movement assures that the shuttle will fall in the same place every time. As the shuttle let drop from left hand, simply allow the right arm to swing the racket forward easily. The racket will meet the falling shuttle at arm's length ahead of the body and continue into to the follow through. The body weight is eased forward from the back foot to the front foot as the service is being delivered.

1.3.9. Low service

In the low serve the flight of the shuttle should reach its highest point on the server's side of the net, falling as it crosses over the net very close to the tape to drop on the short service line. For the low service, the shuttle is guided over the net, rather than hit. Although the wrist controls the final movement of the racket, there is little wrist movement throughout the swing on a low serve. Power is not needed for a low serve, or for a high doubles serve; both are placement strokes. The same easy forward swing used in the low serve is employed for the high doubles serve; the only difference being a quickening of the wrist at the moment of impact in order to direct the shuttle high deep to the back of the service court. Since there is not much strength used in the low serve, or in high doubles serve, the follow through is relatively short but it is most important that the racket is allowed to continue its smooth forward swing. There should be no attempt to stop the racket at contact.

1.3.10. The high singles serve

The high singles serve has the same basic swing as the low serve but since power is needed to hit the shuttle high (twenty four feet high or higher if the ceiling permits) and deep to the base line there is more of everything. The feet are a little wider apart; the racket goes back farther in the back swing; the wrist cocks back more so that it can give additional aid to the forward momentum of the body and arm as whips the racket head forward with all its power to meet the shuttle.

In order to hit the shuttle high and deep without strain on the arm and back muscles, the overall vigorous forward swing of the high singles serve is started by the body weight being transferred, from its prepared balanced position over the back foot, forward on to the front foot.

The impetus of the swing, which should never be hurried, carries the racket forward and upward above head level in a long, smooth follow through. At the end of the follow -through the body weight will be balanced on the ball of the front foot, with toe of the rear foot still in contact with the floor.

1.3.11. Net Shots

The action used here is the push. The wrist movements cocked so that control of the shuttle is maximized. The elbow comes back in preparation for the stroke and the shot is delivered as the elbow joint straightens with the remaining firm. Ideally the shuttle should be taken as close to the top of the net as possible and this is achieved by straightening you arm with your hand positioning upwards at an angle of 45-degree .The net shot is performed with a lunge movement with racket hand and arm but in front of the body. The wrist remains cocked and the forward movement of the arm provides the energy for the stroke. Take the shuttle as early as possible.

1.3.12. Spin net shot

The slicing action used here causes the shuttle to spin making it more difficult for the opponent to control the return, it is achieved by the racket face meeting the shuttle at an angle so that the force applied to the shuttle is to one

side of the centre. The result is the shuttle rotates or spins around a central axis. By changing the direction of the movement of the racket head from downwards to upwards one will cause the shuttle to tumble as well as spin. The wrist is uncocked throughout the stroke while the performing the stroke

1.3.13. Close Net Shots

Even on the most delicate of short, close, hairpin net shots one must use arm and wrist motion to guide the shuttle back over the net shot.

The smash, or kill shot is the main point - winning stroke in badminton. It must, of necessity, be hit from an overhead position and it gives the striker the best opportunity of hitting the shuttle downward at the top maximum speed over the net. The smash is a power stroke essentially demands good body balance and full power of the body, arm and wrist is needed to get the shuttle down as fast as possible. The racket head travels forward faster when you hit a smash than in any other stroke.

Most players first learn to hit a smash from a normal forehand position at point above, and slightly ahead of, the right shoulder. To get full power into a smash one must hit the shuttle ahead of the body. The racket face meets the shuttle squarely and reaches upward and forward to meet the shuttle at the highest possible point. The higher one hit a shuttle from any given position in court the more steeply it can be angled down on to the opponent's court.

The quick action the wrist "throwing" the racket head at the shuttle adds to the snap or peppiness of the well hit smash. More strength, without the final

influence of the wrist, cannot be fully effective. The wrist snap is a movement within the full forward movement of the body and the arm; the wrist snap added more, the shuttle will descend more sharply after smash. Good smashing means hitting the shuttle toward a chosen spot and making it arrive there in the shortest time with the minimum amount of effort.

1.3.14. The Clear

The clear, lob, is a stroke, which sends the shuttle high into the air above the opponent's court. It can be played, either underhand or overhead, from any part of the court. The clear is principally a defensive shot and it normally used gaining time to regain a good defensive position. Good length is the very essence of good clearing. The height, plus depth, supplies the best defensive clear.

When it is expedient to clear from deep in one's own back court, maintain strict adherence to correct foot work and body balance. The shuttle in a full length of the court clear travels over a greater distance than any other shot so this clear must be classified as power stroke. One must apply full strength and good timing to smack the shuttle and deep to land some forty -four feet away -longer if played the cross court. A clear from the overhead position is normally hit with the same preliminary action as a smash directly overhead. Since the force of the blow is outward and upward, the follow through is not so long as in the smash.

1.3.15. The drop shot

The drop shot is a stroke that causes the shuttle to drop steeply close to the net in the opponent's court. It can be played from any part of the court, high or

low, to cross any section of the net-chord in multitudinous variations of flights, especially its flight is slow. Drop shot needs firmness in its stroke that is to guide the shuttle gently just over and near the net to drop shuttle.

1.3.16. The Drive

The drive is a flat stroke that sends the shuttle skimming low over the net in a more or less parallel line with the floor. The shuttle is normally hit around chest height from either side of the body but it can be met at any level between the shoulder and the knee. Obviously, when played from knee level it must be from the backcourt. The drive can be directed to land at varied depths in any part of the opponent's court behind the short service line.

1.4. IMPORTANCE PHYSICAL FITNESS IN BADMINTON

In a study on physical fitness, mental fitness and skill relationship of Badminton, Whetnall and Morris (1981) presented: "Badminton is a game of skill, speed, power and control. Top international players clearly demonstrate the essential stroke techniques and tactics. Studies on the physics of Badminton show that a badminton player needs to have a certain levels of muscular strength, power, local muscular endurance, flexibility and athleticism. It also shows that aerobic capacity and anaerobic capacity are the two most important fitness components in badminton because of the physically demanding nature of the game.

Thus, physical fitness is an inseparable part of sports performance and achievements. The quality of its utilization value is directly proportional to the

level of performance. That means the greater the level of fitness, the greater the ability of a person to attain higher levels of performance.

In the modern game of Badminton, after introduction of rally point system a player is continuously be in movement over a certain period of time (45 minutes to 60 minutes depending upon the standard of the player) varying one's pace from fast to slow, medium and vice versa, and many a time hopping, skipping, jumping, lunging and changing direction while in movement. A typical Badminton match lasts at least 45 minutes so players must possess good aerobic endurance. However, going for a long "steady-state" run does not reflect the demands of the sport. Instead an interval approach to endurance training is more suitable. This demands great deal of cardio vascular endurance on the part of the Badminton player. In an international arena, one can differentiate between top-notches from one another in terms of their fitness level (Cardio-vascular endurance). The deciding factor some times remains with fitness in terms of its finer aspect.

The worlds top most Badminton playing nations, especially China, Indonesia, Malaysia and Korea are very much aware of these and concentrate on development of basic physical fitness variables and related aspects. They start training a child, concentrating on those fitness factors which are supposed to play a significant role in the future performance of a player such as flexibility, agility, balance, cardio-vascular endurance, strength, reaction time and power.(General motor ability qualities)which are appropriate for a specific age group. The standards within fitness are to some extent built into fitness components. The fit

player should be strong, fast, powerful, agile, flexible, lean, athletic, muscular and with a lot of endurance. In addition, there are links to aesthetic standards with respect to the quality of movement. We might also expect the player to be dynamic and explosive. Some of the standards the fit player should attain to meet the demands of the games are strength, power, flexibility, agility, cardio-vascular endurance and other fitness components. The aesthetic standards are not measurable in the same way, for they refer to the quality of the player's fitness. But such aesthetic standards of fitness are dependant on the physical measurable aspect of fitness. A higher level of fitness is often reflected in a better quality of fitness shown in movements around the court. This is to be expected, if this fitness is specific to Badminton and one becomes fit by training on these movements, then necessarily one is going to become a better(more skillful) mover in the game. The fitness and skilled movement of a player's in the game are inseparable in the performance of quality movement, which attains aesthetic standards. The raising of the fitness standards is the key aim for any player who wants to become better in terms of becoming a more complete player, as well as wanting to claim the pyramid of success.

According to Guillain, Jean-Yves (2004) , "Badminton is a highly explosive sport; involving a unique movement technique over a relatively small court area it is an intermittent sport characterized by long bouts of high intensity exercise interspersed with rest periods and entails vigorous movement of both the lower and upper body musculature. It requires quick sprints, stops, starts, lunges, jumps, and rapid changes of direction, twisting, stretching, smashing, clearing,

dropping, and tactically trying to outmaneuver the opponent. The sport demands quick anticipation and response to movements of the opponent, the shuttle, and foot work and stroke production."

Groppel and Roetert (1992) and Lei et al.,(1993) found that the physical requirements of racquet sports demand efficiency in a number of fitness components. To be able to execute advanced strokes or compete effectively against progressively stronger opponents, a player would need to develop higher levels of the basic physical qualities, such as strength, power, muscular endurance, flexibility, coordination and agility.

Omosegaard (1996) found that the most important physical demands in badminton places on its participants are that of aerobic power, maximum concentric and eccentric strength of the hip, knee and ankle extensors, explosive strength and endurance of the hip, knee and ankle extensors as well as explosive and speed strength of the stroke arm. Maximum strength and endurance of the trunk, maximum concentric strength and endurance of the stroke arm and flexibility of the hip and hamstrings are not as important. The least important physical demands badminton places on its participants are that of lactic acid tolerance, maximum eccentric strength of the stroke arm, and flexibility of the stroke arm. The physical fitness components that will be discussed in the following chapters include body composition, metabolism, muscular characteristics, speed, flexibility and agility.

Thus a full-fledged badminton player should possess the agility of an acrobat, the power of a race horse, the killer of a panther, the accuracy of marksman, the sophistication of a dancer, the speed of the a sprinter, the leap of a high jumper, the stamina of a marathon runner, the creativity of an artist, the agility of a gymnast, and so on. The player's judgment has to be sharp and accurate then the player should be repeatedly able to send a shuttle to inner edge of a line and if a shuttle is likely to fall even an inch outside, the player should leave it confidently. Instant co ordination of all the above mentioned faculties is a must for success. The top class world and national players today require speed, power, unlimited endurance and absolutely top physical and mental fitness to withstand a stress and strain of competitions. To attain these qualities one must have adequate physical, physiological and anthropometric parameters.

This research is intended to test scientifically, the association of these parameters with the playing ability of elite badminton players. The physical fitness variables speed, agility, power, cardio vascular endurance, reaction time, shoulder strength and abdominal strength were associated with the playing ability of elite badminton players in this study.

1.5 PHYSIOLOGY

Physiology is the science of functioning of all the organs and systems of an organism. For the physiological system of the body to be fit, they must function well enough to support to specific activity that the individual is performing more over different activity make different demands upon the

organism with respect to circulatory, respiratory, metabolic and neurologic process which are specific to the activity.

In physiology, one learn how the organs, systems, tissues, cells and molecules within cells work and how their functions are put together to maintain the internal environment. Physiology is the science dealing with the study of human body functions. Exercise physiology is the study of how body's structures and functions are changed as a result of exercise. It applies the concept of exercise physiology to training the athlete and enhancing the athlete's sports performance. (Ajmer Singh, 2005)

Exercise physiology is the scientific study of physiological changes in athletes body with the effects of exercise, whether long term or short term. Different environmental changes, namely, altitude, climate, temperature, humidity, nutritional status etc have some close associations with the optimal performance of an athlete. (Morehouse and Miller, 1976)

For the physiological systems of the body to be fit, they must function well enough to support the scientific activity that the individual is performing moreover different activity make different demands upon the organism with respect to the circulatory, respiratory metabolic and neurologic processes which are specific to the activity.

1.6 IMPORTANCE OF PHYSIOLOGY FOR BADMINTON PLAYER

High level of performance in sports and games might be dependent upon the physiological make up and it was recognized that physiological

proficiency was needed for the high level performance. How much athletic ability present in a particular person is attributable to genetics, and how much is determined by training and other adaptations made by the athlete.

Certain body types are well suited to particular types of athletic functions and movements. The Rift Valley of Africa, which includes countries such as Kenya and Ethiopia, has produced more world- and Olympic-champion distance runners than any other place on Earth, due to the slender, relatively long-striding people of that district, who live at altitudes in excess of 6,562 ft (2,000 m). These physical attributes have created a superlative human form for distance running. The people who live near the Baltic Sea in northeast Europe, including Lithuanians and Russians, possess tall, lean, muscular frames, ideally suited to sports such as basketball. These two examples are based on a broad range of experience and athletic success that these groups have enjoyed in the stated sports.

The conflict between how much athletic ability is rooted in individual genetics as opposed to the influence of training and other factors is often expressed as "nature versus nurture." Although precise attribution between athletic nature and nurture are impossible, it is a generally accepted sport science proposition that genes represent approximately 50% of athletic variation in performance, with 50% attributable to both the individual athlete's response to training, as well as social factors, such as the support provided to the athlete in pursuit of his or her goals.

An example is the very tall northern European male, who at a height of 7 ft (2 m) would seem to be a far more attractive recruit to the sport of basketball than a person 5 ft 10 in (1.7 m). The gene-governing height present in the taller male represents a potential dominant physical factor, but never a determinative one, as height is but one component of basketball success. Coordination, agility, spatial sense, determination, resilience, and intelligence are all traits that are essential; each is one that may not be capable of development in an athlete, irrespective of height. The fact that a runner comes from the Rift Valley area of Africa, with the genetic makeup that has been a basis for the multitude of successes for similar athletes in middle distances and the marathon, does not guarantee elite athletic status, as training and the determination to compete against similarly endowed and talented runners will spell the difference.

There are a number of critical training factors constructed upon the inherent individual physical traits that will influence athletic success. The ability to increase one's maximum oxygen uptake, expressed as VO_2 max, is one such factor. A greater VO_2 max represents a correspondingly enhanced ability to convert the bodily fuel sources into energy. VO_2 max is a genetic characteristic that may be typically increased through training between 10% and 15%; exceptional athletes have experienced VO_2 max gains of 30%.

As a further example of the interrelationship between genetic makeup and training determination, studies with elite endurance athletes such as cyclist Lance Armstrong confirm that intense, long-term endurance training

will modify the ratio of fast-twitch, explosive muscle fibers and slow-twitch, endurance fibers present in the musculoskeletal structure, producing more useful sport-specific muscles.

For specific physiological systems of the body to be fit, they must function well enough to support the particular athlete. Since different activities make different demands up on the organism with respect of neurological, respiratory, circulatory and temperature regulating functions physiological fitness is specific to the activity. Physiological systems are highly adaptable to exercise.(Van De Graaff, 2002)

For the purpose of this study, physiological variables are heart rate, blood pressure, body fat percentage, blood hemoglobin concentration, anaerobic power, vital capacity and respiratory rate were selected and their association with the playing ability of elite badminton players.

1.7 ANTHROPOMETRY

"The human body is a machine of wondrous complexity capable of strong and violent movements. This machine is made up of slightly more than two hundred bones to which are attached better than six hundred muscles". (Eston,R., & Reilly, T. 2008)

There are numerous factors, which are influencing performance of sportsman of the physical including shape, size, weight and height. Each and every nation wants to show their supremacy in any sports and games. The Olympic motto itself shows "Faster, higher and stronger". The challenges inspires all nations to exhibit

greater performance in sports through application of research in modern science any technology.

A typical characteristic of body build in a sports men are advantageous in one way or another during the game. In order to dominate and excel in a particular sport, the player must possess all the essential elements required for the performance tasks, and also must have an appropriate body size, shape and proportion. If a player enters a competition for which he is unfit, he does so with distinct disadvantage compared to his opponent who possesses required features for meeting challenges and technology.

To excel in a physically competitive sport, the player must possess such dimensions of body characteristics which suit the most in his/her chosen sport. It is therefore, because of this reason the kinanthropometric or physical characteristics are known to be of fundamental importance for individual development to achieve Olympic and world level performance in sports and games.

Tall stature and long lower extremities have been noticed in all games and events such as volleyball, basketball, high jump, pole vault and goal keeping where jump is involved. The height and reach of players make better performance in games and events.

Under modern circumstances, especially related to training for sports or games or any event with a focus on superior performance emphasis is given for physical stature and body build of each individual participating in any sport of sports and games. Therefore it is evident that the body build popularly known as

physiognomy gets primary emphasis at the time of selection of player concerned where sports superior competitions are involved.

1.8 ANTHROPOMETRIC MEASUREMENTS

Anthropometric measurements have been a part of physical education research and evaluation since its inception. The earlier research was in the area of anthropometry was with the emphasis on changes in muscle size, brought about through exercises.(Clarke and Clarke, 1989)

Physical educators have long realized that the performance of men and women is greatly influenced by such factors of age, height, arm length, leg length and body structure.

The sculpture of Greece and Rome preserve the ideas of those civilizations concerning the idea proportions of the human figure. It is interesting to see in their sculpture the swing of the pendulum of approval from athlete who where broad shouldered, thick set square chested and very muscular, to athletes who are leaner, more supple, and whose figure are more representative of the skills of the finer coordination. Since the early times there has been continued use of anthropometric measurement to determine its relationship with performance in different games and sports.

Anthropometric variables such as weight, standing height, sitting height, foot length, fore leg length, thigh length, leg length and shoulder width are related to optimum and skilful performance in team as well as individual sport.

Physique is a factor insert of success that may lead to inclusion in the Olympic team or more negatively that lack of proper physique may make it almost impossible for an athlete to reach that degree of success. Thus sports anthropometry has emerged as a special branch not only as a parameter or selective diagnostic procedure, but also as a performance prediction tool. Sports scientists and psychologists have been of the opinion that anthropometric measurements and physical components of the athletes have a lot to do with her/his performance in any ground sport. Body measurements vary within the game as well as between the game and sport.

1.9 IMPORTANCE OF ANTHROPOMETRIC VARIABLES

Sports scientists and physiologists have been of the opinion that anthropometric measurements and physical components of an athlete have a lot to do with his performance.

Structure of body is one of the related variables of human motor performance. Science of anthropometry has developed primarily in the play fields of physical anthropologists. Scientific anthropometry began with Johann Friedrich Blumenbach who laid the foundation of craniotomy.

Anthropometric measurements are dimensions of structure of human body taken at specific sites to give measures of length, girth and width. The results can be used to appraise body build, nutritional status and posture. Certain anthropometric considerations somato-type features and racial traits are identified as advantageous

for performance in top sports. An individual for superior performance in any sports is selected based on physical structure of body size he possesses. (Carter, 1982).

These specific measurements of limb length, circumference, breadth, build indices can reveal the relationship between the anthropometry of the athlete and his motor fitness. Measurement of body size included such descriptive inscription as height, weight, and surface area while measures of body proportion describe the relationship between height, weight and arm length, width and circumference of various body segments. It has been found that top athletes in some sports tend to have those proportions that bio mechanically aid the particular performance required.

Human performance is a composition of many variables such as structure of the body, the specific measurements of the limb's circumferences, breadth and body build. Since motor performance is an outcome of various variables, there may be a direct relationship between certain specific measurements and motor performance. The type of individual's structure is an essential factor in his motor performance. Evidence of this is quite common: observe the well proportionate physique of boxers and gymnasts, the super structure of great basketball players, the muscularity of top class football players, the wiriness of champion distance runners and massive built of shot-put and discus throwers. Therefore, anthropometric measurements of an individual player play a dominant role in high level sports performance.

Reilly et al (1990) found the importance of body composition, as an important aspect of fitness. Body composition is also important to the game of

badminton, as excess fat is disadvantageous in moving quickly across court and in leaping to hit the shuttle. According to Maud and Foster (1995), body composition can be predicted from anthropometrical measures.

Reilly et al. (1990), found body fat percentage data for badminton players tends to be scarce, especially for junior players recorded relatively low average body fat percentages for national and international male badminton players respectively.

Reilly et al., (1990) reported that height does not seem to be a determinant of success in badminton as most adult players are taller than the top of the badminton net which is 1.52 to 1.55 meters from the floor.

According to Maud and Foster (1995) , anthropometrics is the science that deals with the measurement of size; weight, and proportions of the human body, as body size and proportions, physique, and body composition are important factors in physical performance and fitness. A standard anthropometrical analysis during a physical fitness assessment would involve determining the height, mass, somatotype and body fat percentage of an individual or athlete.

Even though much has been studied on anthropometry, anthropometrical measurements and the importance of body composition for playing ability, as reported by Reilly et al. (1990), Faccini and DalMonte (1996) and Majumdar et al. (1997) , studies involving anthropometric measurements of badminton players are scarce. Hence, in this research the researcher selected anthropometric

variables, such as height, weight, arm length, leg length and trunk length and to find its association with the playing ability of elite badminton players.

1.10 REASONS FOR SELECTION OF TOPIC

Today performance in sports not only demands systematic training to develop physical, physiological and technical aspect of sports but demands training in consideration of anthropometrical characteristics for success in this field.

There is a lack of descriptive data on the physiological, physical and anthropometrical profile of elite junior Badminton players of India. Junior players are required to have a good stroke production and physical fitness, as well as physiological characteristics that will enable successful performance at the competitive level. The sport-specific technical skills in racket sports are predominant factors. The physical fitness of a player however can be decisive determinant of success during a tournament (Smekal et al., 2001) . Physiological profiling has been recommended in the popular literature Groppel and Roetert (1992) for purpose of fitness assessment and developing norms, as well as for establishing a basis for longitudinal tracking. The test data obtained from physical fitness testing provides a good baseline and reference for coaches, sports scientists, and physiotherapists and for the future researchers. According to Omosegaard (1996), the game of badminton is no exception. Badminton is a very versatile game that makes enormous physical, physiological, psychological, technical and tactical demands, but it is the physical fitness component that will

directly determine the level of demand that can be put on the technical, tactical, physiological and psychological abilities of a player.

Thus, the theoretical foundations made based on different researches proved that badminton players, requires adequate physical and physiological fitness. As reported by Reilly et al. (1990), Faccini and DalMonte (1996) and Majumdar et al. (1997), studies involving anthropometric measurements of badminton players are scarce. Further, it was found that studies associating with the playing ability of badminton between physical, physiological and anthropometric variables are also very limited. Hence, in this research the researcher was interested to find out (1) the association between physical fitness variables, such as, speed, agility, power, cardio vascular endurance, reaction time, shoulder strength and abdominal strength with playing ability of elite junior badminton players (2) the association between selected physiological variables such as, heart rate, blood pressure, body fat percentage, blood hemoglobin concentration, anaerobic power, vital capacity and respiratory rate with playing ability of elite junior badminton players and (3) the association between selected anthropometric variables such as height, weight, arm length, leg length and trunk length and to find its association with the playing ability of elite badminton players.

1.11 OBJECTIVES OF THE STUDY

The aim of the study was to assess the physical, physiological and anthropometrical parameters associated with playing ability of elite junior badminton players. In doing so the researcher would:

(1) Assess the selected physical parameters, such as speed, agility, power, cardio vascular endurance, reaction time, shoulder strength and abdominal strength of elite junior badminton players.

(2) Assess the selected physiological parameters, such as heart rate, blood pressure, body fat percentage, blood hemoglobin concentration, anaerobic power, vital capacity and respiratory rate of elite junior badminton players.

(3) Assess the selected anthropometric parameters, such as, height, weight, arm length, leg length and trunk length of elite junior badminton players.

(4) Assess the playing ability of the elite junior badminton players.

(5) Assess the associations of physical parameters with playing ability; physiological parameters with playing ability; anthropometrical parameters with playing and all the selected variables with playing ability of elite junior badminton players.

1.12 STATEMENT OF THE PROBLEM:

The purpose of the study was to find out the physical, physiological and anthropometrical parameters associated with the playing ability of elite junior badminton players.

1.13 HYPOTHESES

From the scholar's own understanding of the problem and as gleaned through the literature it is hypothesized as

1. The selected physical parameters, such as, speed, agility, explosive power, cardio vascular endurance, reaction time, shoulder strength and abdominal strength would be associated with the playing ability of the elite junior badminton players.

2. The selected physiological variables, such as, heart rate, blood pressure, body fat percentage, blood hemoglobin concentration, anaerobic power, vital capacity and respiratory rate would be associated with the playing ability of the elite junior badminton players.

3. The selected anthropometric variables, such as, height, weight, arm length, leg length and trunk length would be associated with the playing ability of the elite junior badminton players.

4. The badminton playing ability could be successfully associated with the selected physical, physiological and anthropometric parameters.

1.14 SIGNIFICANCE OF THE STUDY

1. The physical educators, coaches and trainers are concerned at times with team selection as well as the training and preparation of the players for competitions. The findings of this study would be helpful for them to scientifically select badminton players for training and competitions.

2. The findings of this study would throw light of the status of physical, physiological and anthropometric parameters of elite junior badminton players. This would help aspiring young players to attain such level of physical and physiological levels.

3. The findings would also helpful to coaches and physical educationists to train aspiring players in badminton to attain such levels of physical and physiological levels.

4. The findings on the association of anthropometric variables with playing ability would throw more light on the benefit of favourable anthropometric measures, which would be helpful to coaches to select players with adequate anthropometric measures.

5. The attempt made in this study, to determine the playing ability of the elite junior badminton players through objective and subjective assessment would be more helpful to the coaches and players to better understand their playing ability in badminton, which in turn would benefit them to attain optimum level of skills of the game.

6. The findings of this study would act as a screening tool based on physical, physiological, and anthropometrical variables.

7. The findings of this study would help to predict badminton playing ability and help to assess improvement throughout the phase of conditioning and training.

8. The report of the study would provide an insight to the parents, coaches, athletes, administrators, scientist, associations and all those concerned; to understand the need of physical and physiological and anthropometrical determination for the performance owing to training load with different ways and means and incorporate suitable programme to facilitate better performance.

9. The study will be of significance in extending the horizon of knowledge in the field of badminton, as the results of the study would provide criteria for team selection.

10. Further the findings of this study would help to prepare specific conditioning and training programmes for the improvement of physical and physiological parameters.

1.15 LIMITATIONS

1. The factors like diet, daily routine habits would be affecting the results of the study, has not been taken into consideration, hence, treated as a limitation to this study.

2. The training facilities, the infrastructure and equipments the elite junior badminton players would have used are bound to differ and these aspects has not been included in the purview of the study, which is considered as a limitation to this study.

3. The type of training that the players undertook in various geographic conditions etcetera would be affecting the playing ability of the players, which is not included in the purview of this research, which is considered as a limitation to this study.

1.16 DELIMITATIONS

1. The study was limited to 50 badminton players who participated in All India Badminton Ranking Tournament in 'under 15' category.

2. The age of the subjects were between 14 to 15years.

3. The study was delimited to the following physical, physiological and anthropometrical variables.

Physical Variables

Speed,

Agility,

Explosive Power,

Cardio vascular endurance,

Reaction Time,

Shoulder strength and

Abdominal Strength.

Physiological Variables

Heart Rate,

Blood Pressure (Mean Arterial),

Body Fat Percentage,

Blood hemoglobin concentration,

Anaerobic Power,

Vital Capacity and

Respiratory Rate.

Anthropometrics Variables

Height,

Weight,

Arm length,

Leg Length and

Trunk Length.

4. The playing ability of the subjects were subjectively tested through three experts in playing situation and objectively tested through four specific skill tests in badminton.

1.17 DEFINITION AND EXPLANATION OF TERMS

1.17.1 Physical Fitness

Physical fitness is the utilization of excessive calories by a cardiovascular and muscular process bringing the body to optimum efficiency. (Clarke and Clarke, 1989).

1.17.2 Speed

Speed may be defined as the capacity of the individual to perform successive movements of the same pattern at a fast rate. (www.freeonlinedictionary.com)

1.17.3 Agility

Agility is the ability to change directions quickly and control body movement.. (Hardayal Singh 1991)

Agility is generally defined as the ability to change direction quickly and effectively while moving as nearly as possible at full speed.

1.17.4 Explosive Power

It is the capacity of the muscles to release maximum force in the shortest period of time is defined as explosive power, projecting the body or an object.

1.17.4 Cardio vascular endurance

The ability to do sports movements, with the desired quality and speed under conditions of fatigue.(Barrow and McGee, 1979)

1.17.5 Reaction Time

Reaction time is the interval of time between the presentation of the stimulus and the inflation of the response.

1.17.6 Shoulder strength

Shoulder strength can be defined as the maximal rate at which a person can exert his strength in performing push ups and was measured by push ups test (Cureton, 1974).

1.17.7 Abdominal Strength.

Muscular strength is defined as the maximum amount of force that a muscle can exert against some form of resistance in a single effort. The strength exerted by the abdominal muscles is defined as abdominal strength and was measured by sit ups tests.(Cureton, 1974).

1.17.8 Heart Rate

The rate at which the heart beats; usually measured to obtain a quick evaluation of a person's health, is defined as heart rate.

1.17.9 Mean Arterial Blood Pressure

It is defined as the average arterial pressure during a single cardiac cycle. As blood is pumped out of the left ventricle into the arteries, pressure is generated. The mean arterial pressure (MAP) is determined by the cardiac output, systematic vascular resistance and central venous pressure according to the following relationship, which is based upon the relationship between flow, pressure and resistance.

1.17.10 Percent Body Fat

A person's body fat percentage is the total weight of the person's fat divided by the person's weight and consists of essential body fat and storage body fat.

1.17.11 Blood hemoglobin concentration

Hemoglobin is a molecule comprised of four subunits. The oxygen carrying ability of blood is directly proportional to its hemoglobin concentration. Hemoglobin determination is used to screen for anemia, to identify the severity of anemia, and to assist in evaluating the patient's response to anemia therapy. Hemoglobin also serves as an important pH buffer in the extra cellular fluid.

1.17.12 Anaerobic Power

The maximum amount of energy that can be generated by the anaerobic energy systems per unit time is defined as anaerobic power.

1.17.13 Vital Capacity

Vital capacity is the maximum volume of air that a person can exhale after maximum inhalation. It can also the maximum volume of air that a person can inhale after maximum exhalation

1.17.14 Respiratory Rate

The number of breaths per minute or, more formally, the number of movements indicative of inspiration and expiration per unit or the rate at which a person inhales and exhales is defined as respiratory rate per minute.

1.17.15 Height

The height of the subject is measured in centimeters in standing erect position. The measuring scale used was a black board. The chin of the subject and the head was slightly held erect (Hockey, 1967).

1.17.16 Weight

Weight is the measurement of total body mass and was measured in Kgs. (Cureton, 1974)

1.17.17 Arm Length

The arm length was the distance from the rod held by the subject tightly in his hands to the acromion process.

1.17.18 Leg Length

The leg length was the measure from the anterior superior iliac spine, to the tip of the medial malleolus, although this may be inaccurate in the presence of pelvic rotation or asymmetry

1.17.19 Trunk Length

Trunk length is defined as a measurement of total height of a person less leg length and recorded to nearest centimeter.