Chapter I

Introduction
CHAPTER – I

INTRODUCTION

1.0 INTRODUCTION

Circuit training is defined as moving quickly from one exercise station to another and completing a prescribed number of exercises in a given time schedule. It is also a form of body conditioning or resistance training using high-intensity aerobics. The aim is to develop strength and muscular endurance. “An exercise circuit” is a single go of all prescribed exercises in the program in a given time period. This program was developed by R.E. Morgan and G.T. Anderson in 1953 at the University of Leeds in England. Circuit training is the most efficient way to enhance not only the muscular strength, but also the muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility. According to Morgan and Anderson the circuit training programs have six to twelve stations focusing on total body conditioning. A complete workout consists of two to three sets of each circuit. Depending on the type of programmes, it may be required to complete a specific number of exercises or for a specified period of time. The break between the sets is usually 15 to 30 seconds. However, any individual can modify the circuit training programme to ensure whether it meets his fitness needs or not.

Aerobic exercises increase the body’s heart rate and hence improve overall fitness and flexibility. Circuit training can be either used to increase cardiovascular fitness, muscle strength or both. Aerobic circuit training primarily focuses on improving an athlete’s cardiovascular fitness. Whereas, circuit training aims to develop strength and muscular endurance. Some exercises which may be used in aerobic circuit training include jogging, using an exercise bike and rowing. Aerobic exercise is defined as a physical exercise that improves cardiovascular fitness. Performing aerobic exercises will usually have a positive effect on
flexibility as well. Circuit training is an effective way of increasing cardiovascular
fitness because it involves a number of different exercises which focus on different
parts of the body. This allows an athlete to work at peak intensity for a longer
period of time. The goal of circuit training is to perform as many repetitions of
exercises in a certain amount of time. These types of exercises generally are not
used in pure aerobic circuit training routines but they can still be a useful addition.
Strength training exercises must be carefully used during aerobic circuit training to
avoid overstraining a muscle. There are five important components of Physical
fitness: Cardio-respiratory endurance, Muscular Endurance, Muscle strength,
Flexibility and Body Composition. This study purely emphasizing on developing
muscular strength, muscular strength endurance, explosive power, cardiorespiratory
endurance, anaerobic capacity, agility and flexibility and to see the changes in
other related components while doing aerobic circuit training.

Cardio respiratory endurance is considered to be the most important
physical fitness component to take part in all the sports activities. This is because,
with reserve oxygen, an activity can be performed with undue fatigue for a
longer period of time. An improved cardio respiratory system helps for an
increase in blood pressure and cardiac output. These changes in this system aid to
respond to the challenges and demands by an individual. When exercise is
performed on a consistent schedule, adaptations are formed in the cardio
respiratory system. Day-to-day tasks are performed more easily as a result of
adaptation. It means that the body is getting more fit to face any challenges in our
life. In other words, the cardio-respiratory endurance is the ability of the heart to
pump blood rich oxygen for the functioning of our muscles. Performing regular
endurance exercise gives improvement to the metabolism and on the cellular level
which in turn improves the body’s ability to use and produce energy more
efficiently. The numbers of capillaries in the muscles are increased. This supplies
the body with more oxygen and allows waste to be eliminated more quickly.
The metabolic changing factors are the muscles which are trained to make most fuel and oxygen so that they can work more effectively.

Aerobic fitness is a measure of the ability to sustain prolonged efforts. It determines the degree of fatigue that almost everybody experiences in his daily life. Higher the aerobic fitness lesser the fatigue level. Aerobic fitness indicates such capabilities as walking, running climbing and other strenuous activities. Therefore, it is an important as well as a basic requirement for many sports and other recreational activities. A high level of aerobic fitness during the growing years indicates a good development of the muscles, bones, and cardio respiratory system. Good aerobic fitness is related to the ability to tolerate the environmental stresses too. Aerobically trained individuals can exercise for longer duration under all circumstances when compared with untrained persons.

Since, cardio respiratory endurance plays a vital role in every sports person’s life, cardio aerobic circuit training schedule is designed to improve the cardio respiratory endurance and other related components such as muscular strength, muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility to produce better results in the performance level.

1.1 TRAINING

Training is a program of exercises designed to improve the skills and increase the energy capacities of an athlete for a particular event (Edward 1984). The term ‘Training’ is widely used in sports. Some experts especially belonging to sports medicine understand sports training as doing physical exercise. Training is the total process of preparation of a sportsman through different means and forms for better performance.

1.2 Sports Training

The very purpose of the training program is an aid in the development of acceptable levels of health – and health related physical fitness and promote the
acquisition of basic movement skills. To achieve these things, training should have some basic principles. Of these, the most basic principle of training is overload. Most physiological systems can adapt to functional demands that exceed these encountered in normal daily life. Training often systematically exposes selected physiologic systems to intensities of work or function that exceed those to which the system is already adapted. The required frequency of training however depends on the season, the athlete, activity and the specific component of fitness. There is no substitute for consistency in a training program.

The athlete might participate in endurance training six times a week and resistance training three times a week. Specificity means the effects of training that are highly specific to the participation of the physiologic system overloaded, to the particular muscle groups used, and to the particular muscle fibers performing the work progression. The training program must progress over several years of participation, so that the appropriate physiological systems will continue to be overloaded. However, too rapid an increase of the training stress may lead to exhaustion and impaired performance. Factors such as age, sex, maturity, current fitness level, years of training, body size, and psychological characteristics of the individual should be considered by the coach in designing each athlete’s training regimen. In large groups in which absolute individualization of training programs may be impractical, the coach should strive for individualization by homogeneously grouping the athletes.

1.3 Types of Training

Success in competitive sports and games can be attributed to many factors and training being one of the most important factors. Different training methods have been commonly used to improve physical fitness and it is related to the standards of performance of athletes. The common training methods are Weight training, Hypoxic training, Aerobic training, Anaerobic training, Circuit training, and Fartlek training. Out of these trainings, the researcher has investigated the “Circuit training program
among university sportsmen”. Circuit training includes high knee action, Push-ups, Squat jump, Sit-ups, Split jump, medicine ball exercise.

1.4 Aims of Sports Training

The major aim of sports training is to achieve high level performance. The sports performance depends largely on physical fitness and motor fitness. The physical fitness can be differentiated into general and specific fitness. Each sports activity demands different types and levels of different motor abilities. When a sportsman possesses these, he is said to have the specific physical fitness of various motor abilities, regardless of any sports which the sportsman possesses. The contribution of physical fitness towards sports performance is indirect. But it should never be overlooked that specific physical fitness depends largely on the general physical fitness (Hardayal Singh, 1983).

1.5 PRINCIPLES OF TRAINING

Training to improve an athlete's performance incorporates the principles of training such as specificity, overload, recovery, adaptation and reversibility.

1.5:1 Specificity

Specificity of training states that sports training should be relevant and appropriate to the sport for which the individual is trained in order to produce a training effect. For instance, to improve the range of movement for a particular joint action, the athlete has to perform exercises that involve in joint action. It is quite possible for an athlete to have good mobility in the shoulder joint but to have poor hip mobility. Conducting shoulder mobility exercises may further improve the shoulder mobility but it will not affect hip mobility.

In addition to developing general levels of all round mobility in an athlete, the coaches need to consider the specific mobility requirements of a given event. The coach can analyze the technique of his event, identify which joint actions are involved and determine which is needed to be improved in terms of the range of movement.
The amount and nature of the mobility training required by each athlete will vary according to the individual athlete's event requirements and individual range of movement for each joint action. It is necessary to measure the range of movement for particular joint actions to determine the present range and future improvement.

Specificity is an important principle in strength training, where the exercise must be specific to the type of strength required, and is therefore related to the particular demands of the event. The coach should have knowledge of the predominant types of muscular activity associated with his/her particular event, the movement pattern involved and the type of strength required. Although specificity is important, it is necessary in every schedule to include exercises of a general nature (e.g. power clean, squat). These exercises may not relate too closely to the movement of any athletic event, but they do give a balanced development and provide a strong base upon which highly specific exercise can be built. Training at low velocity increases low velocity strength substantially but has little effect on high velocity strength (Coyle and Fleming, 1980).

Slow velocity training may be of value in stimulating maximum adaptation within the muscle. Muscle growth (and increase in contractile strength) is related to the amount of tension developed within the muscle (Goldberg, 1975). When an athlete performs high velocity strength work, the force he/she generates is relatively low and therefore fails to stimulate substantial muscular growth. If performed extensively the athlete may not be inducing maximum adaptation with the muscles. It is important therefore, for the athlete to use fast and slow movements to train the muscles.

1.5:2 Intensity

Intensity refers to the quantitative, rather than the qualitative aspect of stimulation and experience. For example, the magnitude or amplitude of sound waves as distinguished from their frequency (Hawely, J 2008).
1.5:3 Frequency

Frequency measures the number of occurrences of a repeating event per unit time (Godfrey, R.J 2005).

1.5:4 Overload

A strength training principle states that the intensity of exercise must be high enough above normal for physiological adaptation to occur. In other words, if one wants to see results when lifting weights, he/she has to lift more than his/her muscles can handle. That overload will cause the muscle fibers to grow stronger and, sometimes, bigger in order to handle the extra load.

When an athlete performs a mobility exercise, he/she should stretch to the end of his/her range of movement. In active mobility, the end of the range of movement is known as the active end position. Improvements in mobility can only be achieved by working at or beyond the active end position. Passive exercises involve passing the active end position, as the external force is able to move the limbs further than the active contracting of the agonist muscles. Kinetic mobility (dynamic) exercises use the momentum of the movement to bounce past the active end position.

A muscle will only strengthen when forced to operate beyond its customary intensity. The load must be progressively increased in order to further adaptive responses as training develops; and the training stimulus is gradually raised. Overload can be progressed by increasing the resistance, increasing the number of repetitions with a particular weight, increasing the number of sets of the exercise (work) and increasing the intensity - more work in the same time i.e. reducing the recovery periods.

1.5:5 Recovery

Recovery implies the physiological processes that restore the body to its pre-exercise condition after exercise. Recovery includes replenishment of muscle glycogen and phosphagen (the energy stores in the muscles); removal of lactic
acid and other metabolites (the waste products of muscle activity); re-oxygenation of myoglobin (the special respiratory pigment which provides muscles with an extra source of oxygen) and replacement of protein (needed to repair muscles damaged during exercise).

Recovery can be accelerated by ensuring body fluids lost in sweat which are to be replaced with water by replacing mineral salts lost in sweat (especially sodium and potassium) and by eating enough nutrients (especially foods that can be converted to muscle glycogen) in order to replace those lost during the exercise. Rest is required in order for the body to recover from the training and to allow adaptation to take place.

1.5:6 Load Progressions

Progression means gradually increasing the amount of exercise. When a performer first starts exercising, their levels of fitness may be poor. If a coach increases the training too quickly, the body will not have time to adapt and this may result in injury. Slow and steady progress is the best way forward.

Gradually increasing the frequency, intensity and duration of fitness sessions are important factors in developing an effective training program. In terms of type of training, progression should be based on the principle of moving from easy activities to difficult ones.

1.5:7 Moderation

Moderation means achieving a balance between “not training enough” and “overtraining”. Achieving the right balance is very important. Without proper rest and recovery time, performers will become too tired to trained effectively and become stressed and irritable.

Even worse, overtraining can lead to injury. This can occur through overstressing joints and tissues, or through poor technique resulting from exhaustion.
1.5:8 Reversibility or Detraining

The ‘Reversibility Principle’ states that athletes lose the effects of training after they stop. During the off season, active participation in other sports or physical activities is essential. The “minimize transfer” is a concept socio-culturally rather than objectively defined.

Improved ranges of movement can be achieved and maintained by regular use of mobility exercises. If an athlete ceases mobility training, the ranges of movement will decline over a period of time.

When training ceases, the training effect will also stop. It gradually reduces at approximately one third of the rate of acquisition (Jenson and Fisher, 1972). Athletes must ensure that they continue strength training throughout the competitive period, although at a much reduced volume, or newly acquired strength will be lost (Godfrey, R, 2005)

1.5:9 Tedium

When planning a training program, it is important to vary the training a bit to prevent performers becoming bored. If every training session is the same, a performer can lose enthusiasm and motivation for training. Hence, it should include a variety of different training methods or vary the type of activity.

1.5:10 Adaptation

Adaptation is the way the body 'programs' muscles to remember particular activities, movements or skills. By repeating that skill or activity, the body adapts to the stress and the skill becomes easier to perform. The Principle of Adaptation explains why a beginning exercisers are often sore after starting a new routine, but after doing the same exercise for weeks and months the athlete has little, if any, muscle soreness. This also explains the need to vary the routine, and continue to apply the ‘Overload Principle’, if continued improvement is desired. The body will react to the training loads imposed by increasing its ability to cope with those loads. Adaptation occurs
during the recovery period after the training session is completed. If exercises lasting less than 10 seconds (ATP-CP energy system) are repeated with a full recovery (approximately 3 to 5 minutes), then an adaptation in which stores of Adenosine triphosphate (ATP) and Creatine-phosphate (CP) in the muscles are increased. This means, more energy is available more rapidly, and increases the maximum peak power output. If overloads are experienced for periods of up to 60 seconds, with a full recovery, it is found that glycogen stores are enhanced. The rate of adaptation will depend on the volume, intensity and frequency of the exercise sessions.

1.6 CIRCUIT TRAINING

Circuit training is an efficient and challenging form of conditioning. It works well for developing strength, endurance, flexibility and coordination. Its versatility has made it popular with the general public right through to elite athletes. For sports men and women, it can be used during the closed season and early pre-season to help develop a solid base fitness and prepare the body for more stressful subsequent training. A well-designed circuit can help to correct the imbalance that occurs in any sport played to a high level. It can also be one of the best types of training for improving strength endurance event like the triathlon. If you haven’t quite reach “elite athlete” status yet, circuit training is superb for general fitness and caters for a wide variety of fitness levels. A great time saver, it can be a refreshing and fun change from the more monotonous type of exercise. Circuit training in itself is not a form of exercise per se, but the way an exercise session is structured. Routines can be developed purely for strength development or for improving endurance or some combination of the two. Circuit classes often seen in gyms and boot camps typically consist of about ten exercise stations completed for 60 seconds in sequence with 30-60 seconds rest between.

While this is a greater structure for some individuals it’s only one of many potential circuit programs and may not be the best approach for endurance athletes for example. Circuit training has been traditionally been as an effective way
to develop both strength and cardiovascular fitness simultaneously. Circuit classes are popular in gyms and with non-athletes because of the variety they offer over continuous exercise such as running and cycling. However, circuit training is not a form of exercise per se, but relates to how an exercise session is structured. A circuit session consists of a series of exercise or station performed in succession with minimal rest intervals in between. This article outlines how to design an effective circuit training program for either general fitness or to improve sport-specific performance. Completing a variety of resistance exercise and high intensity cardiovascular exercise in quick succession can improve both strength and endurance. For individuals short on time, 3-4 brief sessions per week is an effective way to develop all-round fitness. Athlete embarking on a sport-specific strength training program should always start with a phase of basic strength training. This generally occurs during the closed session in the early part of the preparation phase and is used to prepare the body for more strenuous work later on.

Even experienced athletes require a phase of basic strength training as alternating exercises allow for maximum recovery of muscle groups. Increased rest interval between stations is important as this phase of training should not be too intense. Many athletes require good muscular endurance for effective performance in their sport. A circuit training session can be developed to meet their specific needs. By keeping rest intervals short a cardiovascular element is developed and by alternating exercises and muscle groups, more work can be completed for a longer period. Circuit training for a multi-sprint sport such as soccer will differ significantly compared to circuit training for a marathon runner for example. Circuit training can be completed 2-4 times per week. As with resistance training at least 48 hours should be left between sessions that work the same muscle groups. For general fitness a resistance should be chosen that allows the station to be completed for the prescribed period of time 1-2 minutes for example.
Resistance may also be governed by bodyweight and the weight of the implements used, such as medicine balls. Circuit training classes consist of about 8-12 station. These are usually completed for 30-90 seconds with 30-90 seconds rest between each station. Progression can come through either increasing the station time or decreasing the rest intervals. Choose only at a time however. A total of 1-3 circuit is typical with 2-3 minutes rest between each circuit. This type of circuit can also be used by athletes during closed or off session training. Two or three circuit resistance training session can be interspersed with 2-3 cross-training cardiovascular workouts. Sports such as soccer and field hockey benefit consist of respective bouts of high intensity work. Circuit training with station lasting 30-60 seconds, is an ideal way to develop specific strength endurance for these events. The number of exercise in a circuit should be lower than that found in most general fitness circuits and exercise selection should ideally mirror those movements found in competition.

Continuous endurance events such as distance cycling, running and rowing require a different program design. While exercises are still completed on sequence, the length of each station and rest periods bear little resemblance to that of classical circuit training. Very light loads are used so that each exercise can be completed for prolonged period of time. Progression gradually reduces the rest periods between stations to zero, so that in effect each station is completed back-to-back. It’s important to note that while circuit training can improve VO2max, particularly in untrained individuals, it is not as effective as aerobic endurance training for improving aerobic power. It goes without saying that circuit training is complimentary to endurance training and cannot take its place. Conventional circuit training workouts combine various exercise stations to develop both strength and stamina. Circuit training is popular amongst fitness enthusiasts for its challenging nature and individuals pushed a good all-round level of fitness in minimal time. Circuit training is also used by athletes to
develop muscular endurance. The sample circuit training workouts on this page are for general fitness or can be used by athletes in the early pre-season to build a basic foundation of strength. See these circuit training programs and circuit training routine for sessions designed to develop sport-specific strength endurance.

Short-term muscular endurance is required for events that last between 30 seconds and 2 minutes. Certain swimming and running events fall under this duration and strength endurance is required to maintain a high level of work throughout the race. But sports that last much longer than 2 minutes like soccer, field hockey, rugby, boxing, wrestling and martial arts also demand similar short term respective bouts of high intensity activity, often with little rest period in between. The sample circuit training programs below and variation of them can be used to build short-term strength endurance. Athletes competing in continuous endurance events such as distance running or cycling require a different program design. Of course circuit training workout can be used for general fitness or of cross training during the closed season. From an athlete’s perspective, a circuit training program forms just one part of the overall strength training program. It’s particularly effective when it follow a period of maximal weight training as the higher the athletes basic strength is the more of it can be converted into sport-specific muscular endurance. A suitable circuit training program will help athletes to cope with fatigue and tolerate high levels of lactic acid accumulation. A relative low resistance is used circuit station are completed for brief period of time- similar to what might be expected during completion.

There are literally thousands of potential circuit training exercises that can be used to develop a suitable routine. Additionally, many exercises require little or no expensive equipment. With nothing more than a mat and a set of dumbbells, there is scope to develop dozen of routines, even one that is sport-specific. The circuit training exercise below is useful for designing a classic circuit training routine. The one that develop short term muscular endurance. This type of strength
endurance is important in many prolonged sports with intermittent bout of activity, such as soccer and field hockey. These circuit training exercise can also be used by non-athletes to develop general fitness. In this respect, circuit training is very time efficient helping to develop strength and stamina in a single session. Athletes can make use of these general workout too-in the off season for example. Pure endurance athletes still require excellent strength endurance but the nature of their event requires a slightly different approach.

Circuit training method was originally introduced by R.E.Morgan and G.T.Adamson in 1957 at the University of Leeds, England (Kravitz 1996). It is a scientific arrangement of proven exercises performed systematically and repeatedly as a circuit then repeated twice more as circuit (Maxwell L. & Howell 1963). The methodology of circuit training involves various stages as follows: First define both a primary and secondary muscle group/function to work out. Decide two exercises each that will work these two muscles groups/functions (four separate workouts). Decide the order to do the exercises so that give exercises to the primary muscle group (exercise 1), then the secondary muscle group (exercise 2), then back to the first muscle group (exercise 3), then the second muscle group (exercise 4). When go through the circuit, keep the heart rate above 60% or it in difficult to gain much cardiovascular benefit, and keep the heart rate under 85% so the strength improvement. The circuit should last 30 minutes.

Circuit training is a program in which an athlete moves from one exercise station to another in a planned sequence and in the shortest possible time. In planning a circuit training program, exercises are chosen to fit the need of the individual. Each of these exercises is then numbered and assigned to a certain area called station Pasty Neal (1969). Scientific arrangement of proven exercises are performed systematically and repeatedly as a circuit, then repeated twice or more as a circuit Max M.Novich & Buddy Tylor (1970).
The term ‘Circuit’ refers to a number of carefully selected exercises arranged consecutively. Circuit training is a method of exercise that trains the entire body (or just certain muscles) with moderate weight and moderate repetitions. It is an excellent method for achieving general fitness as it incorporates both cardio-vascular (aerobic) conditions with muscular (anaerobic) training. Circuit training can be designed to develop strength, power, muscular endurance, speed, agility, neuromuscular coordination, flexibility, and cardiovascular endurance. Circuit training is probably the most common training regime used by a wide variable of sports activities in order to improve performance. A circuit consists of a number of different stations in which the athlete performs a given time period. When the time is completed the individual moves on to next station and performs a different exercise for a similar period of time and so on around the various station Christopher Connolly (1986). Circuit training is designed to develop cardio respiratory endurance as well as flexibility, strength and muscular endurance in essential muscle group. It is an efficient training method in terms of gain made in short time Donna Mae Miller (1974).

Circuit training can provide vigorous activity in a number of fitness and motor ability activities and is aimed at developing all the basic physical fitness components performed in an interesting an imaginative fashion Perry Johnson & Donald Stolberg (1971). The main purpose of circuit training is to develop strength and endurance at the same time. The exercises can be selected and arranged in such a way that both power and endurance are equally trained or that more emphasis is laid on one of the two. The load should be adjusted to the individual load tolerance. In addition to the exercises and their arrangement, the training programme should lay down the kind and magnitude of additional loads in relation to the individual maximum strength capacity, number of repetitions of each series of exercises, breaks between exercises and after completing the circuit and the number of circuits to be performed Scholich. M. (1979).
Circuit training works for building stronger and shapelier muscles, increases stamina, and is a very quick, safe and efficient method of training. By incorporating very little rest in between set of exercises one can force the heart and lungs to work harder, thus improving their heart rate and lack of rest between sets improves body’s ability to recover from the exercise and developed muscular endurance as well as strength.

Circuit training is an excellent way to simultaneously improve mobility and build strength and stamina. The circuit-training format utilizes a group of 6 to 10 strength exercises that are completed one exercise after another. Each exercise is preformed for a specified number of repetitions or for a given period before moving on to the next exercise. The exercises within each circuit are separated by brief, timed rest intervals, and each circuit is divided by a longer rest period. The total number of circuit performed during a training session may differ from two to six depending on the training level (beginner, intermediate, or advanced), the period of training (preparation or competition) and the training objective.

1.6:1 Salient Features of circuit training

The features of the circuit training are as follows: Circuit Training is flexible and not a rigid one. Based on the availability of time, one can either reduce the number of circuit or extend the number of circuit or extend the number of circuit in their circuit Training programme. If one individual is short on time he/she can do one complete total-body workout in about 10 minutes. If one has time for a more challenging workout, he/she can do up to four circuits, completing up to a 45 minutes workout. Whatever level of fitness, either a beginner, or highly obese he/she can work at a pace that is comfortable for him. The quick pace activity involved in circuit Training is an excellent fat burner. Circuit Training is psychologically rewarding and challenging, offering variety. Circuit Training can be done at home or gym; & circuit Training can significantly improve overall fitness.
Circuit Training has become increasingly popular with regular gym-goers; the reason being, that it provides a one-stop exercise session, combining cardiovascular activity, toning and resistance training. Circuit training is best for beginners and those of average fitness looking to tone up and get in shape (Hardyal singh, 1984). There have been several reports recently, about the variety of benefits one can derive from attending circuit training even just once or twice a week. Studies have concluded that, depending on the structure and balance of the session, one can dramatically improve fitness level by taking part in circuit training exercises. The key to success lies in the formula of performing a set of exercise quickly and in rotation. One can significantly improve cardiovascular fitness level by exercising in short bursts of approximately 60 seconds each. If one individual follows an aerobic work-station with a high repetition and strength station, then the individual will sustain a raised heart rate and therefore get the best possible results. Circuit Training is excellent for developing good basic strength and body tone. The type of rotational activity involved in circuit training is an excellent fat burner.

The benefits of taking part in circuit training can be summed up in few works; “maximum results in the minimum time”. It is probably one of the best methods of exercising, as it provides excellent all round fitness, tone and strength.

1.6:2 Science and Circuit training

There are several established physiological responses to circuit training:

- Greater cardiovascular endurance, When performed consistently over 8-12 weeks, circuit training can increase aerobic oxygen consumption and VO2 max, resulting in greater stamina and overall fitness Osterberg, K. L. & Melby, C. L., (2000).
- Increased muscular endurance and strength

  Resistance training overloads muscles for improved endurance and strength. Strength training is particularly important for women, who lose muscle mass of 1% per year in their 30s and 40s, along with those aged 65 to help minimize bone loss.

- Significant caloric expenditure

  The amount of calories burned per workout depends on its intensity and duration, the exercises selected and the exerciser’s body weight. Circuit training has been reported to burn approximately 500-600 kcal/hour (depending on body weight) however this number increases significantly when exercisers also perform aerobic intervals. During circuit training, heart rates fluctuate between aerobic and anaerobic zones, demanding more calories than either a traditional steady-state cardio or strength session alone. Nutristrategy (2011)

- Improved body composition and higher metabolism

  Research demonstrates that circuit training decreases fat mass, and strength training increases lean body mass, which is more metabolically active than fat. Routine strength training builds muscles that burn more calories both during exercise and at rest (basal metabolic rate) for a higher metabolism, which helps with fat loss and weight management. Gettman, Larry R. and Michael L. Pollock (1981)

1.6:3 Benefits of circuit training

  Numerous investigations have been completed measuring the physiological benefits of circuit weight training. Circuit weight training has been shown to increase muscular strength from 7% to 32% while decreasing the percent of fat from 0.8% to .9% (Gettman & Pollock, 1981). Gettman and Pollock’s review of the literature also have showed an increase of fat-free weight (1 to 3.2 kg) with no subsequent change in body eight. Kilocalorie expenditure has been estimated to be approximately 5 - 6 kcal per minute for women and 8 - 9 kcal per minute for men
(Hempel & Wells, 1985; Wilmore, Parr, & Ward, 1978). In terms of cardiovascular function, studies have shown little to mild improvement in aerobic capacity (5% to 9.5%) from participation in circuit weight training as compared to other aerobic modalities (5% to 25%) (Kass & Castriotta, 1994; Peterson, Miller, Quinney, & Wenger, 1988). Kass and Castriotta support the intention that the mild increases in aerobic capacity are due primarily to increases in fat-free mass from the circuit weight training, and not changes from the main factors affecting aerobic capacity: cardiac output (heart rate x stroke volume) or arterial-venous oxygen difference (exchange of oxygen and carbon dioxide at the cellular level). Traditionally, individuals with cardiovascular disease and hypertension have been discouraged from performing any type of resistance exercise. However, circuit training performed at a moderate intensity (40% of repetition maximum) in cardiac patients has demonstrated significant increases in strength (13% to 40%), with no cardiac or orthopedic complications (Kelemen et al., 1986; Stewart, Mason, & Kelemen, 1988). Furthermore, circuit weight training does not appear to elevate resting blood pressure or heart rate, and may beneficially lower resting diastolic blood pressure in borderline hypertensive (Harris & Holly, 1987). Very little information is available on the psychological benefits of participation in circuit weight training. However, with law enforcement officer’s positive changes in mood, anxiety, depression and hostility have been observed (Norvell & Belles, 1993).

1.7 OVERVIEW OF CARDIOVASCULAR SYSTEM

At rest, the heart provides approximately 5l of blood per minute to meet the energy demands of the average person. As the metabolic demands increase, as might be expected during exercise, the heart is able to compensate by increasing the volume of blood that it pump into circulation. Cardiac output during exercise can increases more than fourfold in an average person, and in an elite endurance athlete, cardiac output may reach 40 L. Mn⁻¹. Like any other muscle, the heart will adapt to the increased demand place on it during prolonged exercise training.
These adaptations are specific to the type of exercise and prolonged endurance and resistance training. The close relationship between the cardiovascular and respiratory system and the effect that exercise has on improved cardio respiratory function are also discussed. The cardiovascular system consists of an elaborate network of vessels (the circulatory system) and a powerful pump (the heart). It is responsible for delivering oxygen and nutrients to active organ and muscle and removing the waste products of metabolism. The heart is a four-chamber muscular organ located in the mid centre of chest cavity. Anterior border is the sternum, and its posterior border is the vertebral column. The diaphragm is inferior to the heart, and the lungs are situated on the lateral border. Approximately two-thirds of its mass lies to left of the body midline. The longitudinal axis of the heart from its base to its apex is directed anterior-inferior and 45° to the left of the midline.

1.7:1 Morphology of the heart

The heart muscle, referred to as the myocardium, is similar in appearance to striated skeletal muscle. However, the fibres of the myocardium are multinucleated and interconnected end to end by intercalated disk. These disks contain desmosomes, which maintain the integrity of the cardiac fibres during contraction and gap junction that allow for a rapid transmission of the electrical impulse that signals for contraction. The structure of the myocardium can be thought of as three separate areas atria ventricular conductive. The atria and ventricular myocardium function similarly to skeletal muscle in that they will contract in response to electrical stimuli. However, an electrical stimulus of only a single cell in either chamber will result in an action potential being rapidly spread to the other cells of the atria and ventricular contractile mechanism. In addition, the cardiac fibres in each of these areas can function separately. The conductive tissue that is found between these chambers provides a network for the rapid transmission of conductive impulses, allowing for coordination action of both the atria and ventricular chambers.
There is a striking difference in the anatomy and physiology of the right and left sides of the heart that relates to their specific functions. The right side of the heart (right atrium) receives blood from all parts of the body, and the right ventricle pump deoxygenated blood to the lungs through the pulmonary circulation. The left atrium receives oxygenated blood from the lungs and pumps this blood from the left ventricle into aorta and through the entire systemic circulation. The left ventricle is an ellipsoidal chamber surrounded by thick musculature that provides the power to eject the blood through the entire body. The right ventricle, however, increscent shapes with thin musculature, reflecting the reduced ejection pressure seen in this ventricle (25 mmHg) compared with approximately 125 mmHg in the left and right ventricles.

Blood flow from the right atrium to the right ventricle goes though the tricuspid valve (consisting of three cups or leaflet that allows only a unidirectional flow of blood). The bicuspid or mitral valve allows blood flow between the left atrium and left ventricle. The semi lunar valves, located on the arterial walls of the outside of the ventricles, prevent blood from flowing back into the heart between contractions. During systole, the cusps lie against their arterial wall attachments, during diastole of during retrograde flow, the cusps fall passively inward, sealing the lumen.

1.7:2 Cardiac cycles

The contraction phase in which the atria or ventricles expel the blood in their chamber is called systole. The relaxation phase in which these chamber refill with blood is referred to as diastole. The cardiac cycle is the total time spent in one complete revolution of systole and diastole. At rest, the heart spends most of its time (approximately 60%) filling with blood (diastole) and less time (approximately 40 %) expelling the blood (systole). However, during exercise this situation is reversed, with most of the cardiac cycle spent in systole. During systole, the tricuspid and mitral valves are closed. However, blood flow from pulmonnic and systemic circulation continues into the atria. As systole ends, the atria ventricular valves
rapidly open and the blood that has accumulated in the atria flows quickly into the ventricles, accounting for 70-80% of the ventricular filling. This period of rapid filling accounts for one-third of diastole is characterized by very little blood flow into the ventricle and is referred to as diastasis. During the last one-third of diastole, ventricle filling is completed with an additional 20-30% of blood pumped into the ventricle as the result of atria systole.

The volume of blood in the ventricle at the end of diastole is called the end-diastole volume (EDV). Two main phases occur during systole, pre-ejection and ejection. The pre-ejection phase includes an electromechanical lag, which is the time delay between the beginning of ventricular excitation (depolarization) and the onset of ventricular contraction and isonomic contraction is the phase in which intra-ventricular pressure is raised before the onset of ejection. This part of the projection phase occurs between the closure of the mitral valve and the opening of the aortic semi lunar valve during the ejection phase, the blood within the ventricle is pumped into the systematic circulation through the opening of the semi lunar valve. This phase ends with the closing of the semi lunar valve. The blood remaining in the ventricle at the end of ejection is referred to as end-systolic volume (ESR). The difference between EDV and ESV is called the stroke volume (SV).

The proportion of the blood pumped out of the left ventricle with each beat is called the ejection fraction (EF) and is determined by SV/EDV. The ejection fraction averages about 60% at rest. This simply means that 60% of the blood in the left ventricle at the end of diastole will be ejected with the next contraction.

1.7:3 Heart Rate and Conduction

A unique feature of the heart is its ability to contract rhythmically, without either neural or hormonal stimulation. This auto-rhythmically is due to a specialized intrinsic conduction system that consists of the senatorial node (SA node), intermodal pathways, atria ventricular node (AV node), and Purkinje fibres.
The SA node is located in the right atrium and is a collection of specialized cells that are capable of generating an electrical impulse. Because of this distinctive ability, it is appropriately nicknamed the pacemaker of the heart. Once an impulse leaves the SA node, it propagates leftward and downward, spreading through the atria sanctum of first the right and then left atria along intermodal pathways to the AV node, which is located toward the centre of the heart on the lower right atria wall.

The AV node, or the AV junction (made up of the AV node and the bundle of His), delays transmission of the impulse for 0.1 s. This slight delay of ventricular excitation and contraction allow the atria to contract and also permit a limitation in the number of signals as protectiveness by the AV node. This appears to serve as a protective mechanism for the ventricles from atria tachyarrhythmia. This bundle of his is found distally in the AV junction and divided into a right and left segment (bundle branches) that transmit the electrical impulses to the right and left ventricles, respectively. The purkinje fibres are found on the distal tips of the right and left bundle branch and extended into the wall of ventricles, accelerating the conduction velocity of the impulse to the rest of the ventricle. The conduction velocity of the purkinje fibers may increase fourfold compared with the bundle of his. As mentioned earlier, the SA node, AV node, and purkinje fibbers have the inherent ability for spontaneous initiation of the electrical impulse. However, the autonomic nervous system can also influence the rate of impulse formation (chronotropy), contractile state of the myocardium (entropy), and the rate of spread of the excitation impulse. The sympathetic and parasympathetic nervous system, as well as certain hormones, can influence cardiac contractility and parasympathetic neurons, whereas the ventricles are primarily innervated by sympathetic neurons. Sympathetic stimulation releases the catecholamine epinephrine and nor epinephrine from sympathetic neural fibers. These neural hormones accelerate heart rate by increasing SA node activity, and they increase both atria and ventricular contractile force. Increases in heart rate are termed tachycardia.
Parasympathetic stimulation through the vagus nerves releases the neurohormones acetylcholine, which depresses SA node activity and decrease atrial contractile force. Decreases in heart rate termed bradycardia sympathetic stimulation may increase heart rate by over 120 beats. Min$^{-1}$ and strength of contraction by 100%, whereas maximal vagal stimulation may decrease heart rate by 20-30 beats. Min$^{-1}$ and lower strength contraction by approximately 30% (Adamovich 1984).

1.8 RESPIRATORY SYSTEM

For the most part, the respiratory system is not a limiting factor in providing sufficient oxygen to the exerting muscles. However, similar in the body, the respiratory system can also adapt to physical exercise in order to maximize its efficiency. In general, lung volume and capacity change very little as the result of physical exercise. Does appear that vital capacity may increase slightly during maximal exercise, but this may be related to the slight decrease seen in residual volume (amount of air remaining in the lungs after a maximal expiration) (Wilmore and Costill 1999).

1.8:1 Overview of Respiratory System

The coordination between the cardiovascular and respiratory system provides the body with an efficient means to transport oxygen to the tissues and remove carbon di-oxide. During respiration, air is breathed in (inspiration) through nasal cavity or mouth. From there the air travels through an elaborate system of branch termed bronchi and bronchioles that expand the surface area for gas exchange. From bronchioles the air reaches the alveoli, that smallest respiratory unit, where gas exchange with the pulmonary circulation occurs. The lungs are located in the chest cavity (thorax) but do not have any direct attachment to the ribs or any other bony structure. Instead, they are suspended by pleural sacs that connect to the both the lungs and thoracic cavity. A fluid is present between the pleural sacs and lungs to prevent friction during respiration.
During inspiration, the muscles of the thoracic cavity (diaphragm and external intercostals) contract, causing the thorax to expand and the lungs to stretch and fill with additional air. The lung expanses causes a reduced pressure gradient and the pressure within the lung is reduced to levels below that on the outside, causing air to rush in. During exercise, additional muscles (e.g., pectorals, sternocleidomastoid) may be recruited, causing a greater movement of the thorax and creating an even larger lung expansion. When air is breathed out (expiration), the inspiratory muscles relax. In the internal intercostals and abdominal muscles causes the thorax to return to its normal position. As a result, the pressure within the lungs expands to levels about that outside and expiration occurs.

Change in the pressure is the primary reason for air and gases to flow into and out of the lungs and through the entire respiratory and circulatory system. For ventilation (the process of inspiration and expiration) to occur, only small changes in pressure between the lungs and outside environment are required. For instance, standard atmospheric pressure is 760 mmHg and only slight changes in intrapulmonary pressure (pressure within the lungs) causes air to be inhaled. This process is not as simple at altitude and will be explained in much greater detail.

### 1.8.2 Effect of training on respiratory system

Training may cause slight decreases in both respiratory rate and minute ventilation during sub maximal exercise this likely reflects the improved exercise efficiency resulting from prolonged endurance training dose appear to cause both respiratory rate and minute ventilation to increases during maximal exercise. During maximal exercise, minute ventilation is thought to increase in relation to increases in Vo2 max (Mcardle, Katch, And Katch 1996). In untrained subjects, Wilmore and Costill (1999) reported that minute ventilation can increases from 120 l. min-1 to about 150 l. min-1 after training. In addition, minute ventilation in highly trained endurance athletes may increase to 180 l. min-1 and has been reported to be as high as 240 l. min-1 in elite rowers (Wilmore and Costill 1999).
Endurance training does appear to reduce the ventilator equivalent during sub maximal exercise (Andrew, Guzman, and Becklake 1966, Girandola And Katch 1976; Yerg et al. 1985). In other world, a reduced amount of air is inspired at a particular rate of oxygen consumption. Thus, the oxygen cost of exercise attributable to ventilation is reduced. The benefit during exercise may be realized by a reduction of fatigue of the ventilator musculature and greater oxygen availability to the exercising muscles (Martin, Heintzelman, and Chen 1982).

Endurance training appears to be a potent stimulus for causing hypervolemia (increases in blood volume). This has been demonstrated in both young and old populations (Carroll et al. 1995; Covertino 1991). During the initial 2-4 weeks of training, plasma volume expansion is thought to account for the hypervolemia (Covertino 1991). As training progresses, blood volume expansion appears to be the result of both continued plasma volume expansion and an increase in the number of red blood cells. The increase in plasma volume is believed to be the result of increase in antidiuretic hormone and aldosterone, which increase fluid retention by the kidney. In addition, exercise causes an increase in plasma proteins, primarily albumin (Yang et al. 1998). This increase in plasma proteins within the blood causes a greater osmotic pull, causing fluid to be retained in the blood.

Increases in blood volume do appear to be the result of both plasma volume expansion and an increase in red blood cell number. However, plasma volume expansion seems to be a greater contributor to hypervolemia (Green et al. 1991). The effect of prolonged endurance training on blood cell volume increase, they do not increase proportionally. Thus, hematocrit (% of red blood cell to total volume) decrease as a response to training. A high hematocrit could be dangerous because of an increased blood viscosity. However, if hematocrit is reduced, the viscosity of the blood will decrease, which may facilitate the blood flow through the circulation. Reductions in hematocrit do not appear to cause a concern for low
haemoglobin concentrations. In fact, haemoglobin concentrations in endurance trained athletes are typically above normal and provide an ample capacity of oxygen to meet the needs of the body during exercise.

1.8:3 Pressure differentials in gases

In addition to changes in pressure that cause inspiration and expiration, pressure differential in the air also result in both oxygen and carbon dioxide exchange. The air we breathe is a mixture of gases. Each gas exerts a pressure in proportion to its concentration in the gas mixture, known as its partial pressure. Air is made up of 79.04% nitrogen, 20.93% oxygen and 0.03% carbon dioxide. Thus, at sea level in which atmospheric pressure is 760mmHg, the partial pressure of oxygen is 15901mmHg (20.93 % of 760 mmHg) and carbon dioxide 0.2mmHg (0.03% of 760mmHg).

As the air reaches the alveoli, the partial pressures of the gases in the alveoli and the partial pressure of the gases in the blood create a pressure gradient. This is the basic of gas exchange. If the partial pressure of gases on either side of the membrane is equal, no gas exchange occurs. The greater pressure gradient, the faster the gases will diffuse across the membrane. As the inspired air moves into the alveoli, the partial pressure of oxygen (PO2) is between 100 and 150mmHg (due to mixing of air within the alveoli). However, alveolar gas concentration remains fairly stable (Wilmore and Costill 1999). The pressure gradient between the capillaries and alveoli is depicted. At the pulmonary capillary, blood as been stripped of most of its oxygen by the tissues. Typically the PO2 at the pulmonary capillary is between 40 and 45 mmHg. As you can see the pressure gradient favours oxygen going from the alveoli to the capillary. In addition, the pressure gradient of carbon dioxide is not as greater at the capillary-alveoli membrane as it is for oxygen. Nevertheless, carbon dioxide diffuses easily across the membrane, despite the low pressure gradient, because of the grater membrane solubility than oxygen.
Oxygen is transported in the blood either combined with haemoglobin (98%) or dissolved in the blood plasma (2%). Each molecule of haemoglobin can carry four molecules of oxygen. The binding of oxygen to haemoglobin depends on the PO$_2$ in the blood and the affinity between oxygen and haemoglobin. The greater the PO$_2$ the more saturated the haemoglobin molecules are with oxygen. In addition, the temperature pH of the blood also affected the affinity between oxygen and haemoglobin. As the pH of the blood decreases the affinity that haemoglobin has two oxygen is decreased and oxygen is released. The right word shift of the curve is known as the Bohr effect and is important during exercise when a greater amount of oxygen is needed in the exercising tissues. On the other hand, when the pH is high, as it would be in the lungs, there is a greater affinity between oxygen and haemoglobin. This is important in order to saturate the haemoglobin molecule with oxygen. In the average male, there is approximately 14-18g of haemoglobin in each 100ml of blood. In the female the concentration of haemoglobin ranges from 12-16g/100ml of blood. Each gram of haemoglobin can bind 1.34ml of oxygen. Thus, for male, the oxygen-carrying capacity of haemoglobin fully saturated with oxygen is approximately 18-24ml/100ml of blood, while in the females the range is approximately 16-22ml/100ml of blood. At rest, normal oxygen saturation is approximately 95-98% (Purden, Siggard-Andersom & Tietz 1987).

Carbon dioxide transport in the blood occurs in the primarily in the form of bicarbonate ions (60-70%). Carbon dioxide is also transported dissolve in the plasma (7%-10%) or bound to haemoglobin. When bound to haemoglobin it forms the molecules carmine haemoglobin. However, it does not complete with oxygen since it has its own binding site on the goblin molecule. In contrast, the binding site for oxygen is on the heme molecule. As carbon dioxide diffuse from the muscle of the blood, it combines with water to form carbonic acid. This very unstable acid quickly dissociates, releasing a hydrogen ion (H$^+$) and forming a bicarbonate ion (HCO$_3$). The H$^+$ bind to haemoglobin and causes the Bohr effect to occur, whereby haemoglobin loses its affinity for oxygen and increases the rate of diffusion of oxygen into the tissues.
1.8:4 Cardiovascular response to acute exercise

Oxygen consumption (VO₂) is elevated during acute exercise to meet the higher energy needs of the exercising muscle. As exercise intensity increases, a greater demand for energy is met by an increase in the cardiac output or by a greater oxygen extraction from the vasculature (a greater (a-\(V\)) \(O_2\) difference). During the early stages of exercise, rapid increases in both heart rate and stroke volume bring about elevation in cardiac output. Exercise on heart rate, stroke volume and cardiac output.

1.8:5 Cardiac output during acute exercise

Cardiac output at rest is approximately 5L. However, during maximal exercise, cardiac output may increase up to 20L in young, sedentary males, and in young, endurance-trained male athletes, cardiac output may reach up to 40L. In examining this considerable difference in cardiac output, we can see that the maximal heart rate for individual from both these groups (assuming that both men are 20 years old) is approximately 200 beats min⁻¹ (maximal heart rate=220-age). Thus, a difference in stroke volume must account for the large differences seen in cardiac output. In our example, stroke volume of the sedentary male is approximately 100ml beat⁻¹, whereas stroke volume in the endurance-trained athlete may reach 200ml beat⁻¹.

The importance of large cardiac output for the endurance athlete is reflected by the linear relationship seen between cardiac output and oxygen consumption (Liwas et al. 1983). The relationship is seen not only in adults but also in children and adolescents (Cunninghan et al. 1984) and between trained and untrained individuals (Hermansen and Saltin 1969). There appear to be a 6:1 ratio between maximal cardiac output and VO₂ max (Mc Ardle, Katch and Katch 1996).
1.9 EXERCISE AND CARDIAC SYSTEM

Heart rate elevation during exercise is primarily controlled by sympathetic stimulation from the higher somotomotor centres of the brain. The heart rate is response is directly proportional and linear to intensity of exercise. As intensity of exercise increases, the heart rate will continue to increase until exercise reaches maximal intensity. At maximal intensity, the heart rate will plateau, indicating at the individual is reaching his or her maximal level.

Initial exercises in heart rate are also related to a withdrawal of parasympathetic input. This occurs during low intensity exercise. As exercise continues in duration, or increases in intensity, a greater sympathetic stimulation becomes the driving force in elevating heart rate. Sympathetic activation occurs from feedback mechanism in both peripheral mechanical and chemical receptors that monitor changes in pH, hypoxia, temperature, and other metabolic variables that can alter sympathetic drive.

During certain activities, an increase in heart rate can be seen before the onset of exercise. This anticipatory rise in heart rate appears to be primarily related to sprint or anaerobic- type events (Mc Ardle, Katch and Katch 1996). As the length of the exercise event increases (from a 60-yard (55-m) sprint to a 2.0-mile (3.2-km) run), the pre exercise heart rate becomes lower. This pattern of an anticipatory heart rate response to high intensity exercise may be a “feed-forward” mechanism provide for a rapid mobilization of bodily reserves, control by the central command centre in the middle of the brain (Mc Ardle, Katch and Katch 1996). Such a mechanism does not appear warranted for longer duration events.

The more times that the Heart beat per minute, the greater the volume of blood pumped into the circulation. However, there is a limit to this effect. As the heart rate rises above a certain level, the strength of each concentration may decrease because of metabolic overload. More important, greater rate of concentration result is less time spent in diastole. The time between concentrations
becomes so reduced that there is not sufficient time for the blood to flow to atria to the ventricles. Thus, the total volume of blood made available to the circulation is reduced. This is why during artificial electrical stimulation the heart rate will only be elevated to between 100 and 150 beats min\(^{-1}\). However, sympathetic stimulation results in a stronger systolic concentration, decreasing time during systole and thereby allowing a greater time for filling during diastole. Elevations in the heart rate from sympathetic stimulation result in a heart rate between 170 and 250 beat min\(^{-1}\).

1.9:1 Stroke volume during acute exercise

Increases in stroke volume are accomplished early during exercise primarily through an increase in the left ventricular end-diastolic volume (EDV). This rapid augmentation of stroke volume is due to the frank-star-ling mechanism, which is related to the increased volume of blood that returns to the heart during exercise. With the greater volume of blood returning to the heart, the ventricles become stretched to a greater extent than normal and respond with the more forceful contraction. This stronger contraction result in a greater volume of blood entering the systematic circulation with each heart beat. This mechanism appears to occur early during exercise and at a relatively low level of exercise intensity. The frank-starling mechanism may cause an approximate 30-50% increase in stroke volume (Bonow 1994). As exercise continues, increases in EDV reach plateau while exercise intensity are still sub maximal. Further increases in stroke volume are attributed to the enhanced left ventricular contractile function (controlled by enhanced sympathetic stimulation), resulting in a greater decrease in ventricular end-systolic volume.

There are two mechanisms that appear to be responsible for the increase in EDV during exercise. The initial mechanism uses the exercising muscles as a pump to increase the rate of return of the blood to the heart. This would be expected to increase the pressures within the ventricular cavity during filling, thereby rising diastolic pressure. However, this does not occur in the healthy heart
and, in contrast, the relaxation seen in the left ventricle reduces the ventricular pressure below that of the left atrium. This causes the mitral valve to open and the onset of ventricular filling. As mentioned earlier, enhanced sympathetic response during exercise increases the relaxation time during diastole. During this time, the increase in size of the left ventricle causes the further reduction in pressure, creating a suctioning effect that draws additional blood into the chamber. This facilitation of the suctioning mechanism by sympathetic drive is the secondary mechanism that contributes to the increased stroke volume and is crucial in the recruitment of the Frank-starling mechanism (Bonow 1994).

1.9:2 Cardiovascular response to training

Long-term physical conditioning results in a number of cardiovascular adaptations specific to the type of exercise program. In general, endurance training and resistance training are the exercise programs that are often compared. These modes of training represent distinctly different physiological demands placed on the cardiovascular system. Although many of the cardiovascular adaptation observed in these training programs are similar, other is very different.

1.9:3 Training’s effect on cardiac output

Increases in vo2 max are characteristic of endurance training programs. These increases are generally accompanied by increases in cardiac output and extraction capability of skeletal muscle (increase in (a-v) o2). The improvement in oxygen exercising muscle. The increase in cardiac output is primarily result of improved stroke volume. Maximal heart rate are unaffected by training and age-matched sedentary individuals. Thus, improvements in cardiac output are directly related to the increase in stroke volume.

1.9:4 Training’s effect on stroke volume

Endurance training has been consistently demonstrated as a potent stimulus for increasing for increasing stroke volume at rest and during maximal exercise.
Endurance-trained athletes have been shown to have a 60% greater stroke volume than sedentary control subjects, which is consistent with the relative difference in VO\(_2\) max seen between these individuals (McArdle, Katch, and Katch 1996). The improved stroke volume is related to an enlarged ventricular chamber (referred to as eccentric hypertrophy) caused by chronic increased preload is thought to relate to the expanded plasma volume associated with such training (Carroll et al. 1995; Convertino 1991).

Resistance training results in little to no change in maximal aerobic capacity. As such, minimal changes would be expected in cardiac output. Significantly greater stroke volumes have been in elite-level weightlifters compared with recreational lifters (Pearson et al. 1986).

However, when this study and other were examined by a meta-analysis (Fleck 1988), the increase in stroke volume seen in these athletes appeared to be more of a factor of a larger body size then a training adaptation.

**1.9:5 Training’s effect on heart rate**

A decrease in resting heart rate and a relative decrease in heart rate at any given sub maximal VO\(_2\) is a commonly found adaptation in endurance training programs (Blomqvist and Saltin 1983, Charlton and Crawford 1997). However, the magnitude in heart rate reduction during endurance training may be much smaller then that reflected in some of the cross-sectional studies comparing elite endurance athletes with sedentary controls (Wilmore et at 1996). Resistance training mayor may not result in any significant change in resting heart rate. Several studies have reported significant decreases in resting heart rate after resistance training programs (Goldberg, Ellit, and Kuehl 1994, Kanakis and Hickson 1980, Stone, Nelson, et al. 1983), whereas others studies have failed to see any significant changes (Lusiani et al. 1986, Ricci et al. 1982, Stone, Wilson, et al. 1983). The mechanism regulating training-induced bradycardia IS not a change in the balance between sympathetic and parasympathetic nativity.
In addition, a decrease in the intrinsic rate of firing of the SA node after long-term training has also been suggested to be a factor in the bradycardia response to long-term training (Schaefer et al. 1992).

1.9:6 Effect of training on respiratory system

Training may cause slight decreases in both respiratory rate and minute ventilation during sub maximal exercise this likely reflects the improved exercise efficiency resulting from prolonged endurance training dose appear to cause both respiratory rate and minute ventilation to increases during maximal exercise. During maximal exercise, minute ventilation is thought to increase in relation to increases in vo2 max (Mcardle, Katch, And Katch 1996). In untrained subjects, Wilmore and Costill (1999) reported that minute ventilation can increases from 120l. Min-1 to about 150 l. Min -1 after training. In addition, minute ventilation in highly trained endurance athletes may increase to 180 l. min-1 and has been reported to be as high as 240l.min-1 in elite rowers (Wilmore and Costill 1999). Endurance training does appear to reduce the ventilator equivalent during sub maximal exercise (Andrew, Guzman, and Becklake 1966, Girandola And Katch1976, Yerg et al., 1985 ). In other world, a reduced amount of air is inspired at a particular rate of oxygen consumption. Thus, the oxygen cost of exercise attributable to ventilation is reduced. The benefit during exercise may be realized by a reduction of fatigue of the ventilator musculature and greater oxygen availability to the exercising muscles (Martin, Heintzelman, and Chen 1982).

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result of increase in ant diuretic hormone and aldosterone, which increase fluid retention by the kidney. In addition, exercise causes an increase in plasma proteins, primarily albumin (Yang et al., 1998). This increase in plasma proteins within the blood causes a greater osmotic pull, causing fluid to be retained in the blood.

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1.10 CARDIO-AEROBIC CIRCUIT TRAINING

Cardio aerobic circuit training is an excellent way to simultaneously increases one’s cardio respiratory capacity, muscular strength and endurance. This training also increases lean body mass by a moderate amount and decrease body fat levels through high levels of energy expenditure (body composition improvement). Cardio workouts help to beat boredom, boost the cardio respiratory endurance. The circuit training format utilizes a group of exercise that are completed sequentially (one exercise after another). Each exercise is performed for a prescribed time period before moving on to the next exercise. The exercises within each circuit are separated by a shorter rest interval, and each circuit is separated by a shorter rest period thus maintaining elevated heart rates during the
circuit workouts and helping the individual to upgrade his cardio respiratory capacity. The total number of circuits performed during a training session may vary from two to six depending on one’s training level.

1.10:1 Objectives behind the cardio aerobic circuit training programme

1. The circuit work will increase general work capacity by improving ability to tolerate increasing levels of muscular fatigue (stamina improvement).

2. Over time, the circuit training will have shorter and shorter rest intervals between exercise, thus maintaining elevated heart rates during the circuit workout and helping the person to upgrade cardio respiratory capacity (stamina improvement).

3. Circuit efforts will enhance overall body strength, including the strength and resiliency of muscles, tendons and ligaments, the integrity of joints, and the strength and density of supporting bone structures (strength improvement).

4. The circuit will improve movement skill and body awareness, because a person will perform exercises that utilize body weight as the primary form of resistance (skill improvement).

5. The circuit program will increase lean muscle mass by a moderate amount and decrease body-fat levels through high levels of energy expenditure (body composition improvement).

1.10:2 Cardio-Circuit training (CCT)

A cardiovascular workout simply involves elevating the heart rate to anywhere from 60-80% of one’s maximum (depending on the goals - 60% for fat burning, up to 80% for fitness). It is not necessary that one has to run, because any activity that keeps the heart rate up will suffice, and CCT helps to maintain the heart rate. The benefit of CCT is that one can do it in the privacy and convenience of their own space. What one requires is a small space around to perform the various exercises, and there's no expensive equipment involved. Since the person is moving from one exercise to the next, there's no boredom associated with hours on a treadmill.
Circuit training allows work on the cardiovascular system while simultaneously working on strength. Since the participant is constantly progressing through the workout, the heart rate will remain elevated, and the exerciser will reap the same benefits as the person who logs all those miles on the treadmill. This type of training is far superior to steady-state exercises when it comes to increasing clients’ VO2 (the amount of oxygen a person can uptake during exercise). Circuit training also stimulates the mind, which keeps boredom at bay.

It is to be noted that members performing long-duration and moderate intensity exercise, (as this may put participants in a catabolic state,) they will start losing muscle mass. Hence, it is important to test the importance of determining appropriate intensities through metabolic testing. Determining VO2 at various intensities and aerobic threshold, among other variables, will allow safe, effective and results-driven activity. Monitoring intensity and recovery with a heart rate monitor will enhance outcomes and provide an additional motivating variable to participants.

The effects on specific muscle fibers should also be considered. Slow-twitch muscle fibers are more compatible with short, intense bouts of exercise such as sprinting (group cycling) and weightlifting. When training in one of these modes, the muscle tissue has a tendency to take on the appropriate properties. As an illustration, imagine a marathon runner and a sprinter. The sprinter is composed of fast twitch muscles and carries a great deal more muscle mass, whereas the marathon runner has a lot of thin, slow-twitch muscle fibers. This may be extreme to prove a point; however, it is easy to see how much of a difference the type of training has on body shape.

Due to fewer rest periods, there will be a greater release of testosterone during circuit training, which helps muscles to grow. While it is true that performing a long aerobic session will lower the testosterone level and release cortisol (which causes the body to break down muscle tissue), this workout session will not take that long to complete. Therefore, the time required to start this
cortisol-releasing process will not be reached. Finally, since participants move through the workout quickly, they will not have to spend long hours in the fitness centre, and will be able to spend more time doing the things they never seemed to have time or energy to do. **Stephen A. Black (2006)**

### 1.11 AEROBIC TRAINING

Endurance is one of the most difficult disciplines, but it is to the one who endures that the final victory comes. These are the beautiful verses of Buddha which signifies not only mental but also physical endurance. Here comes the easy method of maintaining a perfect figure and gain endurance - aerobics. As the name suggests, Aerobics is an exercise that combines the rhythmic steps of aerobics with graceful dance movements. It can be broadly divided into four types - high-impact exercises, low-impact exercises, step aerobics and water aerobics. High impact exercises involve intense jumping actions that are synchronized with the rhythmic beats of the music being played.

The word aerobic means "with oxygen" but aerobics usually refers to any kind of activity that gets heart pumping and muscles using oxygen. Aerobic dancing involves any kind of exercise put to music and can include everything from country music line dance aerobics to hip-hop dancing. It's recommended that kids and teens get at least 20 minutes of good aerobic exercise three times a week, so aerobic dancing can be a fun way to stay in shape.

Aerobic exercise is any activity that can be practiced continuously over a longer period. It is a type of exercise that works the body at the lower end of the target heart rate zone, causing the heart and lungs to adapt by becoming stronger. The step test is a sub maximal test for estimating aerobic fitness. It is commonly used in studies involving large numbers of people, like the cardiac fitness. When the body is challenged with a bout of physical exertion, like stepping up and down, the heart rate increases to deliver oxygen to the working muscles. The efficiency with which the muscles perform the challenge is reflected in the
increase in heart rate. The body adapts to regular physical activity by becoming more efficient. A lower heart rate at the end of the 3-minute step test indicates greater aerobic fitness (i.e., more fit). Higher fitness levels are indicative of an active lifestyle, which is what the people strive for.

1.11:1 The Effects of Aerobic Exercise

There are numerous performance benefits by doing regular aerobic training. The training increases storage of energy molecules such as fats and carbohydrates within the muscles, allowing for increased endurance, neuro-vascularisation of the muscle and sarcomeres to increase blood flow through the muscles. Aerobic training increases the aerobic capacity of an individual. Aerobic capacity describes the functional status of the cardio respiratory system including the heart, lungs & blood vessels. Aerobic capacity is defined as the maximum volume of oxygen consumed by one’s muscle during exercise Bouchard, (2009). It is a function of one’s cardio respiratory performance and of the ability of the muscles to extract the oxygen and fuel delivered to them. Higher aerobic capacity means higher the level of aerobic fitness. Regular aerobic training improves the efficiency of the complete respiratory system. The respiratory pathways and the area for exchange of gases are constantly used and increased blood flow is present in these areas. This improves the efficiency of the respiratory system.

Important factors that are necessary for exchange of gases are increased surface area of the alveoli and a reduced thickness of the membrane of the alveoli. Regular exercise causes continuous movement of air in and out of the lungs in large volumes and as a result the elasticity and surface tension of alveoli are greatly increased. This helps in faster exchange of oxygen and carbon-dioxide across the membrane of the alveoli. Laurence, (1967)
During heavy aerobic exercise with the increased active movement of the respiratory muscles the oxygen consumption of the ventilator muscles increases to about eight to ten percent of the total oxygen consumption of the body. This increase in oxygen cost of the respiratory muscles is sufficient to meet the demands of strenuous exercises.

Training results in an increase in the efficiency of oxygen transport within the body. By lowering the resting HR, and heart rates at sub maximal load, the heart pumps more blood with every heart beat. This, and other physiological changes, increases the oxygen transport capability (Cyril et al, 1985). When an individual is tested before and after training, while performing exercise at the same load, a lower HR is shown after training, because more blood (thus, oxygen) is delivered in each heart beat. Such HR differences during exercise can be used to predict aerobic fitness. Since a fit person shows a lower hr than an unfit one when exercising at the same load (same oxygen uptake) and the maximal HR for each age group is known, it became possible to extrapolate the oxygen uptake –HR curve to the maximal HR where it represents vo2 max.

1.11:2 Aerobic Circuit Training

Aerobic circuit training is mainly determined by the duration of the exercise (work bout) and by the amount and type of rest given between exercises. In "aerobic circuit training" aerobic stations like a treadmill, rower, bike, or stepper (one to five minutes per station) are interspersed with weight-training stations. This protocol has been found to increase aerobic stamina and muscular endurance and strength. By adding a 30-second to 3-minute (or longer) aerobics station between each station, referred to as aerobic circuit training. This method attempts to improve cardio respiratory endurance as well. Variations of this aerobic circuit-training model include performing 2, 3, 4 or more exercise stations in series, and then performing the aerobics station.
For instance, a meta-analysis done on circuits showed that a 10-exercise circuit (using weights) using a 30 seconds for both work and recovery, performed 3 times per week over 8-12 weeks improved VO2max (measure of aerobic capacity) by 5%. While comparing this to that of continuous running, cycling or rowing at around 75% of max heart rate for 20-30 minutes, three times a week for 8-12 weeks, which boosts VO2max by around 20%. Obviously, this 30s work: 30s rest protocol is not optimal for yielding staggering aerobic improvements. However, other studies have shown that by shortening the rest period to 15 seconds or jogging during a 30 second recovery bout improved VO2 max by 12% and 18%, respectively. Aerobic circuit training is unlike any other exercise programs because it is not dependent upon equipments & machines to accomplish the exercises. This means that you can do aerobic circuit training in the comfort of any games. The best part of aerobic circuit training is the psychological motivation of the performer.

1.11:3 Uses of Aerobic Circuit Training

Increased cardio-vascular endurance, Generally tends to increase overall energy levels. In some cases it can increase mood (as in making a person feel "happier"). However it is not known whether this is because of increased self-esteem due to factors such as weight loss and increased energy levels or simply due to the release of endorphins during exercise (but it's probably a little of both). Increased storage of energy molecules such as fats and carbohydrates within the muscles, allowing for increased endurance. Neovascularisation of the muscle sarcomeres to increase blood flow through the muscles. Increasing speed at which aerobic metabolism is activated within muscles, allowing a greater portion of energy for intense exercise to be generated aerobically. Improving the ability of muscles to use fats during exercise, preserving intramuscular glycogen. Enhancing the speed at which muscles recover from high intensity exercise.
1.12 MOTOR FITNESS COMPONENTS

1.12:1 Muscular Strength

Muscular strength clearly contributes to vertical jump performance, but whether or not an athlete's jump performance will be improved by concentrating on improving absolute strength seems to depend on how strong the athlete is at the initiation of a training program. Thus, vertical jump performance improved markedly following strength training in subjects who began training with only average strength Adams et al., (1992); Bauer et al., (1990); Clutch et al., (1983), but very little in previously strength-trained individuals Hakkinen & Komi, (1985).

Muscular strength is generally defined as the ability to generate force at a given velocity of movement. One of the five primary components of physical fitness, is generally developed using resistance training. This type of training typically aims to stimulate increased strength on a number of physiological levels. Individual strength is an indicator of overall health, or a measure of progress during resistance or rehabilitation training programme. As such, there are a number of available methods for testing physical strength.

Exercises for muscular strength

Dumbbells, barbells, strength bands, weight machines and cables can all be used as resistance to increase strength. Compound, multi-joint movements with free weights are most effective for increasing strength. Muscle fiber recruitment typically works from smallest to largest, the largest being those responsible for power. The Big Three: the squat, dead lift and bench press, are commonly used to improve strength. Jonathan Lawson and Steve Holman of Iron Man Magazine recommended using the "Ultimate Exercise" for each muscle group. Performing these strength-component exercises in a repetition range from 3 to 6 reps per set is very effective for increasing muscular strength.
1.12:2 Muscular strength and endurance

Muscular strength and endurance is defined as the ability to exert sub-maximal effort repeatedly over time. Muscular endurance is very different from muscular strength and endurance exercises use the aerobic capacity of muscles to produce energy via the Krebs cycle. Long bouts of exercise utilize Type I slow-twitch muscle fibers. Contrary to fast-twitch fibers, they have high resistance to fatigue and possess high mitochondria and capillary density. The low Creatine and glycogen content means more triglycerides for efficient energy production. Endurance fibers allow muscles to sustain contraction for long periods of time. Muscular endurance is often measured with a sit-up test or by using 80 percent of 1RM until muscular failure on any given exercise.

Muscular strength is the ability to exert maximal force (using maximum or near maximum resistance) during limited repetitions. When focusing on strength improvements, player generally working to increase your power and muscle mass, with gains in muscular endurance being secondary. Muscular endurance is the ability to exert sub-maximal force (using less than maximum resistance) during repeated repetitions. Endurance focuses on working to increase muscle’s ability to work over a period of time, with gains in power and muscle mass being secondary. Strength and endurance training should not be just a one-dimensional improvement program. By combining them with programs such as cardio and mental conditioning, one can develop into a total football package.

Exercises for muscular endurance

Endurance exercises can increase the cellular mitochondria and capillary density of muscle fibers. Typical endurance exercises include aerobic activities like running, jogging, swimming, cycling, triathlons and decathlons. Body weight exercises are useful because they use both strength and endurance. The U.S. military has long used such exercises as running, pull ups, sit ups and body squats to increase strength and endurance quickly. Circuit training involves repeated circuits of several different exercises, with very little rest, and is another way of training for endurance.
Benefits of increasing strength and endurance

There are many benefits to incorporating both strength and endurance training into one’s regimen. Both forms of exercise decrease the risk of injury by helping to build stronger ligaments and tendons. Bone density also improves with both endurance and strength training, helping to prevent osteoporosis. Regular exercise has been shown to lower blood pressure, raise good cholesterol levels and increase resting metabolic rate. In fact, the more muscle one have, the more calories they have to burn every single day. The more calories one can burn, the more food they can enjoy and it can also been beneficial to the mind in terms of increasing the feel-good endorphins, which are produced during strength and endurance exercise.

1.12:3 Explosive power

It is the ability to release maximum force as fast as possible. It is a maximum muscular contraction against a resistance in a minimum amount of time. Power = Force x Velocity. It is a compound element of motor fitness. It needs specific muscular strength, speed of limb movement and skill in integrating and co-coordinating the action. Increased velocity of the body is related to improved neuromuscular initiation, co-ordination and precision of movement patterns. When a highly skilled level is attained, further performance improvement is primarily attributable to the increase in strength. Muscular power exists in its own right. Strength and power are separate entities.

Successful sporting performance at elite levels of competition often depends heavily on the explosive leg power of the athletes involved. Many team sports also require high levels of explosive power, such as Basketball, Volleyball, Netball and the Rugby and Football codes for success at elite levels of competition. Explosive power comes from the development of speed strength and pure strength. Power represents the amount of work a muscle or muscle group can produce per unit of time. Until recent years, power as it relates to sports
performance has been the subject of limited research, but in the last decade or so researchers has realized the importance of training for power in a wide variety of sporting activities (Clutch et al., 1983).

Vertical and horizontal jumping, in its many different forms, requires high levels of explosive muscular power. Power is the equivalent of explosive strength. The term "speed-strength" is synonymous with power. Paavolainen et al., (1999) suggested that muscle power is the ability of neuromuscular system to produce power during maximal exercise when glycolytic and oxidative energy production is high and muscle contractility may be limited.

The strength of the muscles in the limbs is moving and supporting the weight of the body repeatedly over a given period of time in terms of dynamics strength, and sometimes, it has been called velocity or speed. The important aspect of this factor is the requirement that the muscular force must be repeated as many times as possible. Explosive strength and dynamic strength involve movement of the body or of its limbs.

Successful sporting performance at elite levels of competition often depends heavily on the explosive leg power of the athletes involved in many individuals’ sports such as track and field events, gymnastics and diving. The ability to use high levels of strength as quickly and as explosively as possible is essential to perform elite levels. Many team sports also require high levels of explosive power, such as Basket ball, Volley ball, Net ball, and the Rugby and Foot ball. The explosive power comes from the development of speed strength and pure strength. The power represents the amount of work as muscle or muscle group can produce per unit of time. Until recent years, power as it relates to sports perform has been the subject of limited research but in last decade or so, the researchers have realized the importance of training for power in a wide variety of sporting activities vertical and horizontal jumping in its many different forms, that requires high levels of explosive muscular power. The double legged Volley ball
spike jump and block jumps are very different in technique, but fundamentally they are similar. Basketball players typically jump from one leg to perform a layup, and from two legs to rebound jump, again both are very different styles of jumping which are fundamentally similar in their movement patterns. Different jumping styles also involve very different approaches and run-ups which increase or decrease the velocity of the moment performed, depending on the type of jump. It has been suggested that different styles of jumping require different strength properties and that training for one type of jumping technique will not necessarily improve performance in another style of jumping.

There have been many research studies that have investigated leg power as it relates to standing brought jump, and how to develop leg power through various weight training, and plyometric training techniques. Data has been produced for many elite individual and team sport athletes for physical and physiological characteristics, including standing vertical jump scores, related to specific sports performance. There is limited research available however, comparing athletes of different sporting disciplines in standing brought jump ability. This study is an attempt to explain why athletes in some sports perform better standing brought jump than athletes in other sports. Author Zekria (1949) Bosco et al., (1982), Schmidtbleicher et al., (1988) have cited the variables that can be measured using a simple electronic contact mat with a timing device to record the contact and flight times Bosco (1992). A detailed explanation of the methods for assessing various muscle functions during a vertical jump is given by Bosco (1992).

It is intuitively obvious that the ability to generate force rapidly is a major contributor to vertical jump performance. As an example, a very strong individual who tries to smoothly execute the vertical jump movements slowly over a period of 10 years will never leave the ground. To examine the maximal rate of force development, scientists determine the maximal slope of the early portion of the force
the time curve during maximal strength tests rate of force production and the resulting value which is termed as the maximal rate of force development (MRFD).

In support of the notion that the maximal rate of force development is important to vertical jump performance, many investigations have shown that (MRFD) is a very significant factor in explosive performance Behm & Sale, (1993), Hakkinen & Komi, (1985), Schmidtbleicher, (1992). Surprisingly, however, a recent study on the rate of force development and metrically contracting muscles reported a poor relationship between MRFD and vertical jump performance Young & Bilby (1993). Thus, one is faced with the dilemma of which joint angle to test when attempting to predict dynamic performance through an entire range of the movement, as in a vertical jump. Therefore, it may be more appropriate to use dynamic MRFD tests in which a constant load (isoinertial) rather than an isometric load is used.

It is not surprising that training-induced improvements in maximal force during slow movements do not usually produce great improvements in MRFD or in vertical jump ability. In fact, such training might even reduce the ability of the muscles to develop force rapidly Hakkinen (1989). On the other hand, vertical jump training with light loads increases an athlete's ability to rapidly develop force Hakkinen et al., (1981). Although heavy resistance training increases maximal strength (and thus the highest point on the force time curve), this type of training does not improve vertical jump performance appreciably, especially in athletes who have already been strength trained for more than 6 m. This is because the time during which the feet are in contact with the ground or floor while executing a vertical jump is typically less than 350 ms, and most of the training-induced increases in force-producing potential cannot be realized over such a short time.

A heavier athlete obviously must generate a greater power output to jump a given height when compared to a lighter athlete. It is a common belief that strength training should be minimized when training for vertical jump improvement because additional body weight should be avoided, even if that extra
weight consists largely of increased muscle mass. However, an increase in muscle cross-sectional area is always accompanied by an improvement of relative strength and, therefore, an improved power-to-weight ratio Schmidtbleicher, (1992). This is evident in the exceptional vertical jumping ability and 30 m sprinting performances of many heavy athletes such as American football players, weight throwers, and weightlifters Hatfield, 1989, Schmidtbleicher (1992). Thus, strength training cannot be justifiably excluded from a vertical jumping training program for the reason that an athlete might gain muscle mass.

1.12:4 Cardio respiratory endurance

Cardio respiratory endurance is the ability to perform a given task at a given intensity for a given period of time. All sports require some degree of Cardio respiratory endurance, but exactly what kind is specific to the sport, position, and even the individual athlete. Physically, Cardio respiratory endurance is dependent on the level of development of the appropriate energy pathways as well as physical strength. Neutrally, Cardio respiratory endurance is dependent on sporting skill and movement efficiency. As it is apparent, like the other building blocks, Cardio respiratory endurance also heavily crosses over with the other components. When they refer to Cardio respiratory endurance, most people are referring to energy systems development. There are three energy systems, each providing energy for a certain time span before exhausting its stores. The adenosine-triphosphatase / phosphorcreatine (ATP/PCr) energy pathway provides the majority of the energy for activities lasting 0-3 seconds. The anaerobic glycolytic (AG) energy pathway provides most of the energy activities lasting 4-50 seconds. And the aerobic pathway provides most of the energy for activities lasting longer than 50 seconds (Brooks, 1996).

Different sports require different levels of energy systems development based upon their pace and duration. For instance, a sprinter would need to spend most of his time development the AG pathway, while a marathoner would focus
on the aerobic pathway. Since the energy pathways are largely separate, it is important to note that, at least in this sense, Cardio respiratory endurance means different things for different people. Continuing with the physical makeup of Cardio respiratory endurance, strength is a major determinant. The higher a given load is relative to an athlete is maximum strength, the more closely related Cardio respiratory endurance and strength will be. Higher strength levels allow for a greater “reserve.” (Brooks and White 1996).

1.12.5 Anaerobic capacity

Aerobic basically means with oxygen and anaerobic means "without oxygen". Anaerobic capacity, as we've already established is the power produced without the requirement for oxygen to be present. Sprinting, at the end of a race, is predominantly an anaerobic activity. And as all know power at these intensities can only be sustained for a short period of time.

The answer lies in the energy systems and pathways used to create the power that propel our bikes. Sprinting and other high energy outputs, attacking, jumping gaps etc, are powered by the ATP-PC energy systems. The ATP system (Adenosine Triphosphate) is sustainable for one to four seconds and the PC system (Phosphate Creatine) will power the anaerobic activity from four seconds until the PC system runs out; which is possibly up to twenty seconds in well trained athletes. A graphic sample of the exhaustion of the ATP-PC energy systems can be seen at the end of a race with a long sprint. When the sprint starts from a long way out the one's who didn't preserve their ATP-PC systems, or never developed them in the first place through proper training, are the ones going backwards.

From the aspect of energy demands and energy sources engaged, it can be stated that basket ball undoubtedly appertains to the group of anaerobic sports, if being on play for the entire game time, on average accomplish 6000 – 7000 meters of running, perform up to 40 various jumps, 280 movement direction changes, 120 ball catches, 80 passes, 16 shooting for a goal and 36 dribbling. S.Trini Coll.Antropol.25 (2001)
1.12.6 Agility

In general, agility is defined as "the ability of a system to rapidly respond to change by adapting its initial stable configuration.

Agility is the ability to change the body's position efficiently, and requires the integration of isolated movement skills using a combination of balance, coordination, speed, reflexes, strength and endurance. Agility is the ability to change the direction of the body in an efficient and effective manner and to achieve this to require a combination of: balance - the ability to maintain equilibrium when stationary or moving (i.e. not to fall over) through the coordinated actions of our sensory functions (eyes, ears and the proprioceptive organs in our joints); static balance - the ability to retain the centre of mass above the base of support in a stationary position; dynamic balance - the ability to maintain balance with body movement; speed - the ability to move all or part of the body quickly; strength - the ability of a muscle or muscle group to overcome a resistance; and lastly, co-ordination - the ability to control the movement of the body in co-operation with the body's sensory functions (e.g. catching a ball [ball, hand and eye co-ordination]).

In sports, agility is often defined in terms of an individual sport, due to it being an integration of many components each used differently (specific to all of sorts of different sports). It is a common testing variable measured during most athletic performance variables to measure. A variety of different agility test can be selected. However, agility testing provides more relevant information if the test selected incorporates movements that are similar to the movements the athlete performs during competition and if the test is part of the athletic training program. (Sheppard JM, Young WB 2006).
1.12:7 Flexibility

Flexibility is the ability to move a muscle or a group of muscles through the complete range of motion. All stretching exercises should be preceded by a warm-up. The elevated muscles temperature and increased mobility of connective tissue and joints generated by the warm-up allow for a greater range of motion to be reached during each stretching exercise. Flexibility exercises are generally performed before exercises or competition but may also be performed afterward during the cool-down period. Stretching during the post exercise cool-down period should be performed within a short time of the conclusion of practice or competition (5-10 min.) to take advantage of the elevated muscle temperatures. Post exercises stretching may also decrease muscle soreness (Prentice 1983). However, there is little experimental evidence to support this contention.

The muscle proprioceptors, Golgi tendon organs and muscle spindles, are sensory neural fibres that relay information about the muscle stretch to the upper neural pathways. Their primary responsibility is to protect the muscle from injury. The Golgi tendon organs are located in the tendons of the muscle fibres, and the muscle spindles considered intra fusel fibers and are situated parallel to the muscle fibers. Golgi tendon organ are sensitive to tension development in the muscle tendon complex. They inhibit contraction of agonist muscles and activation of antagonist muscles. When tension within the muscle tendon complex is increased to a level, that poses a risk of injury to the muscle. The muscle spindles are responsible for monitoring the stretch and length of the muscle and initiating contraction within the muscle to reduce the stretch if need.

As the muscle lengthens during a stretching exercise, the muscle spindles become activated, causing a contraction of the muscle that is being stretched. During a rapid stretch that might be seen in a ballistic or bouncing type movement both the tension in the tendon organ and muscle spindles activated, causing a rapid contraction of the muscle. This stretch reflex is easily demonstrated by a light tap
to the patellar tendon and the consequent contraction of the quadriceps muscle to ease the tension on the muscle spindles and Golgi tendon organs. It is for this reason that slow static stretching, which result in a more relaxed and effective stretch, is recommended (Alter 1996).

**Physiological factors of flexibility**

As we age, the elasticity of the muscle is reduced resulting in a decrease in range of motion. Reduced elasticity is caused by increased fibrous cartilage replacing degenerative muscle fibres, increased adhesions and cross-link within the muscle, and increased calcium deposits (Alter 1996). However, flexibility training can still be beneficial in an older population, as demonstrated by the improved range of motion (ROM) in elderly subjects after 10 weeks of stretching exercises performed 3 days per week (Girouard and Hurley 1995).

Gender also appears to affect muscle and joint flexibility. Females tend to be more flexible than males at all ages. This is primarily attributed to gender difference of pelvic structure and hormonal concentrations that may affect the laxity of connective tissue (Alter 1996).

Physical activity is an important determinant of flexibility because active people tend to be more flexible than sedentary individuals (Kirby et al., 1981, M.C. Cue 1953). Inactivity causes tightening or contraction of inactive muscles and this is easily understood considering the stiffness one feels after sitting for a prolonged period. During long duration of inactivity as result of deconditioning or immobilisation, the connective tissue of the muscle become shortened, reducing its range of motion around a joint.
1.13 STATEMENT OF THE PROBLEM

The purpose of the study was to find out the effect of circuit training and cardio aerobic circuit training on muscular strength, muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility of University sportsmen.

1.14 OBJECTIVES OF THE PRESENT STUDY

The objectives of the present study were:

1. To identify the status of players in Bharathiar University in various sports on muscular strength, muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility.

2. To study the individualized training effect of twelve weeks of Circuit training on muscular strength, muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility of University Sportsmen.

3. To study the individualized training effect of twelve weeks of Cardio aerobic Circuit training on muscular strength, muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility of University Sportsmen.

4. To compare the effects of two modalities of training namely Circuit training and Cardio aerobic circuit training with traditional method of training(Control Group) on muscular strength, muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility of University Sportsmen.

5. To compare the effects of Circuit training with Cardio aerobic circuit training on muscular strength, muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility of University Sportsmen.
6. To identify the superior model of training to be used for University sportsmen to develop the motor fitness components muscular strength, muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility.

7. To find out the nature and difficulty of circuit and cardio aerobic circuit training during twelve weeks of training period.

**1.15 HYPOTHESES**

The following are the hypothesis of the present study.

1. In studying the individualized effects, it was hypothesized that Circuit training may have significant improvement over the period of twelve weeks training on muscular strength, muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility of University Sportsmen.

2. In studying the individualized effects, it was hypothesized that the Cardio aerobic Circuit training may have significant improvement over the period of twelve weeks training on muscular strength, muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility of University Sportsmen.

3. While studying the individualized effects, it was hypothesized that the control group may not have any significant improvement over the period of twelve weeks on muscular strength, muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility of University Sportsmen.

4. In studying the comparative effects, it was hypothesized that Circuit training and cardio aerobic circuit training may have significant improvement over the period of twelve weeks training on muscular strength, muscular strength...
endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility of University Sportsmen than the control group

5. While studying the comparative effects, it was hypothesized that Cardio aerobic Circuit training group may have significant improvement over the period of twelve weeks of training on muscular strength, muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility of University Sportsmen than the circuit training group.

1.16 SIGNIFICANCE OF THE STUDY

The present study is significant in view of the following aspects:

1. The salient feature of the applications of Circuit Training and Cardio Aerobic Circuit Training used in the present study to focus towards the development of muscular strength, muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility.

2. This study would contribute more to the sports society for the effective use of Circuit Training and Cardio Aerobic Circuit Training for various sports population to the improvement of muscular strength, muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility.

3. The Circuit Training and Cardio Aerobic Circuit Training used in the present study were scientifically structured one. Hence, it was believed that players treated with these training modules can be benefited in time with regard to the development of major motor fitness components of University sportmen.

4. The present study would provide a scientific base and guidance to the physical educationists, coaches, sports scientists, exercise physiologists and fitness leaders to design a combined training programme using the training modules in the present study with the view to develop the variables related to muscular strength, muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility.
5. One of the basic objectives of the present study was to extract the full potentials from the players through feasible means and methods. Having the usage of full potentials, the low achievers can be easily made as high achievers. It helps them to participate in the major sports in competitions successfully.

6. Finding of this research study would give a basic knowledge to the trainers and fitness leaders to envisage and conduct further research in various training methods, training programs, training intensity and training load to enhance the performance of players.

7. Physical educationists and sports scientists have been constantly examining sports performance in relation to major motor fitness components. The findings of such type of studies could be utilized in the practical aspects of coaching and training.

8. The findings of the study would provide guidance to physical education teachers and coaches to prepare training schedules for specific games on the basis of the physical capacity of players.

9. This study would help in creating awareness and the significance of cardio aerobic training.

10. The findings of this study add to the quantum of knowledge in the area of training methods.

1.17 DELIMITATIONS

The present study is delimited in the following aspects:

1. The study is delimited to forty five sportsmen studying in various department of Bharathiar University, Coimbatore and Tamilnadu State.

2. The age group of the subjects has been ranged from eighteen to twenty five years only.

3. The study is delimited to selected motor fitness components namely muscular strength, muscular strength endurance, explosive power, cardio respiratory endurance, anaerobic capacity, agility and flexibility.
4. Training program of the present study has been delimited to circuit training and cardio aerobic circuit training only.

5. Training period for the purpose of this study has been delimited to twelve weeks only.

1.18 LIMITATIONS

The following factors have been considered as limitations of the present study.

1. The influence of certain factors like life style, daily routine work, diet and other factors on the results of the study were not taken into account.

2. No attempt was made to control the factors like air resistance, intensity of light atmosphere and temperature during training and testing period.

3. The differences in socio economic and educational back ground of the subjects were not taken into account.

4. The influence of knowledge of the subjects in exercise science and their previous experience during physical activities were not taken into account.

5. Since the subjects were motivated verbally during testing and training periods no attempt was put to differentiate their level of motivation

6. The effect of uncontrollable factors like heredity and environment were not considered as limitation of this study.

1.19: DEFINITION OF OPERATIONAL TERMS

1.19:1 Muscular strength

It refers to the strength or the ability of a muscle or muscle group to exert maximal force. It is expressed as the participant’s repetition maximum (e.g. 1RM Leg press)
1.19: 2 **Muscular strength endurance**

It indicates the ability of a muscle to exert sub maximal force repeatedly over a period of time (e.g. curl-ups)

1.19: 3 **Explosive power**

It implies the ability to exert maximum muscular contraction instantly in an explosive burst of movements. The two components of power are strength and speed. (e.g. jumping or a sprint start)

1.19: 4 **Cardio respiratory endurance**

Cardio respiratory endurance refers to the ability of the body to perform prolonged, large-muscle, dynamic exercise at moderate-to-high levels of intensity. Cardio respiratory endurance is an important part of overall physical fitness.

1.19: 5 **Anaerobic capacity**

During anaerobic work, involving maximum effort, the body is working so hard that the demands for oxygen and fuel exceed the rate of supply and the muscles have to rely on the stored reserves of fuel.

1.19: 6 **Agility**

Agility is defined as "the ability of a system to rapidly respond to change by adapting its initial stable configuration".

1.19: 7 **Flexibility**

‘Flexibility is the ability to move joints’. Flexibility is defined as the ability to do wide range of movement at joints. It indicates the capacity to bend and extend the body parts without any difficulty beyond the normal position.