CHAPTER – I

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Training is a programme of exercise, designed to improve the skills and to increase the energy capacity of an athlete for a particular event. Therefore training is essential for the development of physical fitness components (William and Sperryn, 1976). It is the process of sports protection based on scientific and pedagogical principles for higher performance (Singh, 1991).

1.1. PLYOMETRIC TRAINING

Speed and strength are integral components of fitness found in varying degrees in virtually all athletic movements. Simply put, the combination of speed and strength is power. For many years, coaches and athletes have sought to improve power in order to enhance performance. Throughout this century and no doubt long before, jumping, bounding and hopping exercises have been used in various ways to enhance athletic performance. In recent years, this distinct method of training for power or explosiveness has been termed plyometrics. Plyometrics is based on the understanding that a concentric muscular contraction is much stronger if it immediately follows an eccentric contraction of the same muscle.

Plyometrics, also known as "jump training" or "plyos", is a set of exercises in which muscles exert maximum force in short intervals of time, with the goal of increasing power (speed-strength). This training focuses on learning to move from a muscle extension to a contraction in a rapid or "explosive" manner, such as in specialized repeated jumping (Chu, 1998). Plyometrics is primarily used by athletes, especially martial artists, sprinters and high jumpers, to improve performance, and is
used in the fitness field to a much lesser degree. A thorough warm up is essential prior to plyometric training. Attention should be given to jogging, stretching (dynamic), striding and general mobility especially about the joints involved in the planned plyometric session.

The term "plyometrics" was coined by Fred Wilt after watching Soviet athletes prepare for their events in track and field; he felt this was a key to their success (Wilt and Yessis, 1984). It is a poor term to describe what happens, but it has since been accepted and is now well established. When Wilt learned of the work being done by Michael Yessis on Soviet (Russia) training methods, they quickly collaborated to help disseminate information on plyometrics.

Since its introduction in the early 1980s, two forms of plyometrics have been evolved. In the original version of plyometrics, created by Russian scientist Yuri Verkhoshansky, it was defined as the shock method (Yuri, 1966). In this, the athlete would drop down from a height and experience a "shock" upon landing. This in turn would bring about a forced eccentric contraction which was then immediately switched to a concentric contraction as the athlete jumped upward. The landing and takeoff are executed in an extremely short period of time, in the range of 0.1-0.2 seconds. The shock method is the most effective method used by athletes to improve their speed, quickness, and power after development of a strong strength base.

Plyometrics (the shock method) was created by Yuri Verkhoshansky in the late 1960s and early 1970s. Since then, the shock method of plyometrics is still being practiced for improvement of athletic performance by what appears to be a relatively
limited number of athletes. These athletes still do depth jumps, the key exercise in the shock method, according to the guidelines established by Verkhoshansky.

Most athletes execute simple and complex jumps and call them plyometrics rather than jump training as it was called in the past. This includes the depth jump which was executed in ways different from what was recommended by Verkhoshansky. This form of jump training is very popular but plyometrics is a buzzword for all types of jumps, regardless of how long it takes to execute the jump. Its use is so pervasive that it is even possible to find push-ups described as being plyometric.

Due to the wide use and appeal of the term plyometrics, the true meaning of plyometrics as developed by Verkhoshansky has for the most part been forgotten. Verkhoshansky was well known and respected worldwide in both the scientific and in the coaching arenas. He was relatively unknown in the United States except for some of his articles that were translated and published in the "Soviet Sports Review", later called the "Fitness and Sports Review International."

In addition to creating the shock method, Verkhoshansky is credited with developing the stretch-shortening concept of muscle contractions and the development of specialized (dynamic correspondence) strength exercises. Plyometrics, or more specifically the shock method, is considered a form of specialized strength development.

Before undertaking plyometric training, it is necessary to distinguish jumps that are commonly called plyometric and true plyometric jumps as exemplified in the depth jump which is illustrative of the shock method. Since its inception in the former Soviet Union as the shock method, there have been other forms of the plyometric exercises created by Yessis that do not involve jump exercises. For details and illustrations of
these exercises see "Explosive Running" and "Explosive Plyometrics" (Yessis, 2009). These exercises involve the stretch-shorten concept that underlies the shock method.

In the depth jump, the athlete experiences a shock on landing in which the hip, knee, and ankle extensor muscles undergo a powerful eccentric contraction. For the muscles to respond explosively, the eccentric contraction is then quickly switched to the isometric (when the downward movement stops) and then the concentric contraction, in a minimum amount of time (Medvedev., Marchenko., Fomichenko, 1983). This allows the athlete to jump upward as high as possible. In the eccentric contraction, the muscles are involuntarily lengthened, while in the concentric contraction, the muscles are shortened after being tensed. Most of the stretching and shortening takes place in the tendons that are attached to the muscles involved rather than in the muscles. To execute the depth jump, the athlete stands on a raised platform, usually not greater than 20–30 inches (51–76 cm) high, and then steps out and drops down in a vertical pathway to make contact with the floor. The exact height used by most athletes is usually quite low in the early stages of training. The key is how high the athlete jumps in relation to the height of the takeoff platform. Technique and jump height are most important at this time. While the body is dropping, the athlete consciously prepares the muscles for the impact by tensing the muscles. The flooring upon which the athlete drops down on should be somewhat resilient, mainly for prevention of injury. Upon making contact with the floor, the athlete then goes into slight leg flexes to absorb some of the force for safety. However, the main role played by the muscles and tendons is to withstand the force that is experienced in the landing. This force is withstood in eccentric contraction.
When muscle contraction is sufficiently great, it is able to stop the downward movement very quickly.

This phase is sometimes called the phase of amortization in which the athlete absorbs some of the force and stops downward movement by the strong eccentric contraction of the muscles. The strong eccentric contraction prepares the muscles to switch to the concentric contraction in an explosive manner for takeoff.

When the athlete drops down to the floor, the body experiences an impact upon landing. The higher the height of the step-off platform, the greater the impact force upon landing. This creates a shock to the body which the body responds to by undergoing a strong involuntary muscular contraction to prevent the body from collapsing on the ground. This in turn produces great tension in the muscles and tendons which is then given back in a return upward movement. The faster the change in the muscular contractions, the greater the power created and the resulting height attained.

More specifically, the muscles and tendons undergo a stretch (eccentric contraction) while landing which is needed to absorb some of the force generated but most importantly, to withstand the force that is produced by the shock that occurs on the landing. The greater the shock (forces experienced on landing), the stronger the eccentric contraction will be, which in turn produces even greater tension. This tension which is potential force, is then given back in the return movement when the muscular contractions switch to the concentric or shortening regime (Yessis, 2009).

However, for maximum return of energy, minimum time must elapse from when the force is received to when they are returned. The greater the time between receiving the forces and giving them back, the less is the return and the less the height that can be
achieved in the jump. Most of the lengthening and shortening occurs in the respective muscle tendons which have greater elasticity.

Another way of saying this is that the faster the switching from the eccentric to the concentric contraction, the greater will be the force produced and the greater the return movement. The speed of the switching is extremely fast, 0.20 seconds or less. For example, high-level sprinters execute the switch from the eccentric contraction that occurs when the foot hits the ground to the concentric contraction when the foot breaks contact with the ground in less than 0.10 seconds. In world-class sprinters, the time is approximately 0.08 seconds. The exact platform height used by most athletes in the depth jump should be less than 30 inches (76 cm) in the early stages of training. Most athletes start at approximately 12 inches (30 cm) after doing some jump training. They then gradually work up to 20 inches (51 cm) and then to 30 inches depending upon how well the jumps are executed. The main criterion is that the athlete is jumping as high as possible on every jump.

If the athlete gradually improves his jump height, the same platform height is continued until increases in jump height are no longer observed. At this time, takeoff height is increased by a few inches. If the athlete continually fails to jump very high, the height of the drop-down is lowered somewhat (Volkov and Koryagin, 1976). Most important here is how high the athlete jumps after the drop-down.

The maximum platform height used by a high level athlete is no more than 40 inches (100 cm). Rather than developing greater explosive power this height leads to more eccentric strength development. Going higher than 30 inches (76 cm) is usually counterproductive and may lead to injury. This occurs when the intensity of the forced
involuntary eccentric contraction, upon landing is greater than the muscles can withstand. In addition, the athlete will not be able to execute a quick return (fast transition between muscular contractions), which is the key to successful execution of explosive plyometrics.

Because of the forces involved and the quickness of execution, the central nervous system is strongly involved (Masalgin, Y.V., Verkhoshansky, L.L., Golovina, A.M., Naraliev., 1987). It is important that the athlete not overdo using the shock plyometric method. Doing so will lead to great fatigue, and, according to Verkhoshansky, sleep disturbances. Athletes have great difficulty sleeping well if they execute too many depth jumps. This indicates that athletes must be well-prepared physically before doing this type of training.

Technique of jumping is also very important when executing plyometric exercises. In essence, the athlete goes into a slight squat (crouch) upon landing in which the hip, knee, and ankle joints flex. The takeoff or jump upward is executed in a sequence initiated by hip-joint extension followed by knee-joint extension which begins during the hip-joint extension. As the knee-joint extension is taking place, ankle-joint extension begins and is the only action that occurs as the takeoff (breaking contact with the ground) takes place. All three actions contribute force to the upward jump, but the knee-joint extension is the major contributor.

Plyometrics have been shown to have benefits for reducing lower extremity injuries in team sports while combined with other neuromuscular training (i.e. strength training, balance training, and stretching). Plyometric exercises involve an increased risk of injury due to the large force generated during training and performance, and should
only be performed by well conditioned individuals under supervision. Good levels of physical strength, flexibility, and proprioception should be achieved before commencement of plyometric training.

The specified minimum strength requirement varies depending on where the information is sourced and the intensity of the plyometrics being performed. Chu (1998) recommends that a participant be able to perform 50 repetitions of the squat exercise at 60% of his or her bodyweight before doing plyometrics. Core (abdomen) strength is also important. Flexibility is required both for injury prevention and to enhance the effect of the stretch shortening cycle. In fact, some advanced training methods combine plyometrics and intensive stretching in order to both protect the joint and make it more receptive to the plyometric benefits. Proprioception is an important component of balance, coordination and agility, which is also required for safe performance of plyometric exercises.

The maximum force that a muscle can develop is attained during a rapid eccentric contraction. However, it should be realised that muscles seldom perform one type of contraction in isolation during athletic movements. When a concentric contraction occurs (muscle shortens) immediately following an eccentric contraction (muscle lengthens) then the force generated can be dramatically increased.

If a muscle is stretched, much of the energy required to stretch it is lost as heat, but some of this energy can be stored by the elastic components of the muscle. This stored energy is available to the muscle only during a subsequent contraction. It is important to realise that this energy boost is lost if the eccentric contraction is not followed immediately by a concentric contraction. To express this greater force the
muscle must contract within the shortest time possible. This whole process is frequently
called the stretch shortening cycle and is the underlying mechanism of plyometric
training.

1.2. RESISTANCE TRAINING

Resistance training is any exercise that causes the muscles to contract against an
external resistance with the expectation of increases in strength, tone, mass, and
endurance. The external resistance can be dumbbells, rubber exercise tubing, your own body weight, bricks, bottles of water, or any other object that causes the muscles to contract.

Resistance training is a form of strength training in which each effort is performed against a specific opposing force generated by resistance. Resistance exercise is used to develop the strength and size of skeletal muscles. Properly performed resistance training can provide significant functional benefits and improvement in overall health and well-being. According to the American Sports Medicine Institute (ASMI) we have to "gradually and progressively overload the musculature system so it gets stronger." Research showed that regular resistance training will strengthen and tone muscles and increase bone mass. Resistance training should not be confused with weightlifting, power lifting or bodybuilding which is competitive sports involving different types of strength training with non-elastic forces such as gravity rather than immovable resistance. Full range of motion is important in resistance training because muscle overload occurs only at the specific joint angles where the muscle is worked.

Resistance training increases muscle strength by pitting muscles against a weight, such as a dumbbell, barbell or other types of resistance. A rubberized band can even be
used. Resistance training can increase muscle strength and bone density and reduce body fat. Resistance training also called weight training or strength training; is pitting muscles against a resistance such as a weight or other type of resistance, to build the strength, anaerobic endurance, and size of skeletal muscles. A well-rounded program of physical activity includes strength training to improve bone, joint function, bone density, muscle, tendon and ligament strength, as well as aerobic exercise to improve our heart and lung fitness. These activities should work all the major muscle groups of our body (legs, hips, back, chest, abdomen, shoulders, and arms).

Building strong leg, arm and abdominal muscles along with other muscle groups will assist in the execution of sports fundamentals and the enjoyment of the game. All strength training involves the microscopic tearing of the muscle fibers by exceeding their capacity to move a weight or resist a force. As the body rebuilds the fibers, strength increases. Strong leg and arm muscles will increase a player’s ability to maintain balance on their skates and increase the force exerted while skating. Strength is also useful in the games when they are pushing an opposing player in order to get the tackle and off, it has to do with muscle strength.

Strength training is the use of resistance to muscular contraction to build the strength, anaerobic endurance, and size of skeletal muscles. There are many different methods of strength training, the most common being the use of gravity or elastic/hydraulic forces to oppose muscle contraction. See the resistance training article for information about elastic/hydraulic training, but note that the terms "strength training" and "resistance training" are often used interchangeably.
When properly performed, strength training can provide significant functional benefits and improvement in overall health and well-being, including increased bone, muscle, tendon and ligament strength and toughness, improved joint function, reduced potential for injury, increased bone density, a temporary increase in metabolism, improved cardiac function, and elevated HDL (good) cholesterol. Training commonly uses the technique of progressively increasing the force output of the muscle through incremental increases of weight, elastic tension or other resistance, and uses a variety of exercises and types of equipment to target specific muscle groups. Strength training is primarily an anaerobic activity, although some proponents have adapted it to provide the benefits of aerobic exercise through circuit training.

Weight and resistance training are popular methods of strength training that use gravity or elastic/hydraulic resistance to oppose muscle contraction. Each method provides a different challenge to the muscle relating to the position where the resistance to muscle contraction peaks. Weight training provides the majority of the resistance at the initiating joint angle when the movement begins, when the muscle must overcome the inertia of the weight's mass. In contrast, elastic resistance provides the greatest opposition to contraction at the end of the movement when the material experiences the greatest tension while hydraulic resistance varies depending on the speed of the submerged limb, with greater resistance at higher speeds. In addition to the equipment used, joint angles can alter the force output of the muscles due to leverage.

The basic principles of strength training involve a manipulation of the number of repetitions, sets, tempo, exercises and force to cause desired changes in strength, endurance, size or shape by overloading of a group of muscles. The specific combinations of reps, sets, exercises, resistance and force depend on the purpose of the
individual performing the exercise: sets with fewer reps can be performed using more force, but have a reduced impact on endurance.

1.2.1. Benefits of Resistance Training

Regular resistance training offers many benefits. Strength training increases bone density and reduces the risk of osteoporosis. It helps us to control our body weight at the same time we can gain the muscles power. When gaining muscles power our body muscles efficiently burns more calories. Strength training builds the muscles; it protects the body joints from injury and boosts our stamina when we grow stronger. We won’t fatigue as easily. It helps us to maintain our flexibility and balance and helps us remain independent even in our aged stage. It can also boost our self-confidence, improve the body image and reduce the risk of depression. People who regularly take part in strength training will get a better night’s sleep. It can reduce the sign and symptoms of many chronic conditions including arthritis, back pain, depression, diabetes and obesity.

The benefits of resistance training include greater muscular strength, improved muscle tone and appearance, increased endurance, enhanced bone density, and improved cardiovascular fitness. Many people take up resistance training to improve their physical attractiveness. Most men can develop substantial muscles; most women lack the testosterone to do it, but they can develop a firm, toned physique, increase their strength by the same proportion as that achieved by men. An individual's genetic make-up dictates the response to weight training stimuli to some extent.

1.3. SPEED

Speed is essential for many physical activities. Without speed there is no sports and physical education. Speed of muscle contraction is an innate quality, but speed of
movements can be gained through movements. Speed is a valuable factor in games like football, basketball, hockey and track events etc. Strength is highly related to speed. Generally more teams win because they are the faster teams.

Speed is the quickness of movement of a limb, whether this is the legs of a runner or the arm of the shot putter. Speed is an integral part of every sport and can be expressed as any one of, or combination of maximum speed, elastic strength and speed endurance. Speed is also influenced by the athlete's mobility, special strength, strength endurance and technique. Energy for absolute speed is supplied by the anaerobic alactic pathway. The anaerobic and alactic (without lactate) energy system is best challenged as an athlete approaches top speed. The technique of sprinting must be rehearsed at slow speeds and then transferred to runs at maximum speed. The stimulation, excitation and correct firing order of the motor units, composed of a motor nerve and the group of muscles that it supplies, makes it possible for high frequency movements to occur. The whole process is not very clear but the complex coordination and timing of the motor units and muscles most certainly must be rehearsed at high speeds to implant the correct patterns.

1.4. STRENGTH

Strength is needed in all kinds of work and physical activity. Muscles that are strong result in better protection of body joints and fewer sprains, strains and other muscular difficulties. Furthermore, muscle strength helps to maintain proper posture and provides for greater endurance, power and resistance to fatigue. Strength is also a very important element in the field of sports. The best athletes pay particular attention to develop strength in various muscle groups.
An individual's physical strength is determined by two factors; the cross-sectional area of muscle fibers recruited to generate force and the intensity of the recruitment. Individuals with a high proportion of type I slow twitch muscle fibers will be relatively weaker than a similar individual with a high proportion of type II fast twitch fibres, but would have a greater inherent capacity for physical endurance. The genetic inheritance of muscle fiber type sets the outermost boundaries of physical strength possible (barring the use of enhancing agents such as testosterone), though the unique position within this envelope is determined by training. Individual muscle fiber ratios can be determined through a muscle biopsy. Other considerations are the ability to recruit muscle fibers for a particular activity, joint angles, and the length of each limb. For a given cross-section, shorter limbs are able to lift more weight. The ability to gain muscle also varies from person to person, based mainly upon genes dictating the amounts of hormones secreted, but also on sex, age, health of the person, and adequate nutrients in the diet.

1.5. CARDIO-RESPIRATORY ENDURANCE

The main factor which limits and at the same time affects performance is fatigue. An athlete is considered to have good endurance when he does not easily fatigue, or can continue to perform in a state of fatigue. Endurance, of all the bio-motor abilities, should be developed first. Without endurance it is difficult to repeat other types of training enough to develop the other components of fitness.

Cardio-vascular response to exercise is greatly increased blood flow to active muscle in proportion to other organ tissues, deliver oxygen to the working tissue, cells and to remove carbon dioxide and other waste products from the tissue cells. During exercise, arteries feeding the working muscle dilate increasing blood flow. Other blood vessels feeding tissue with less metabolic demand constrict. The major cardio-vascular
response to exercise other than increased blood flow is the increased ability of active tissue to extract more oxygen already carried in the blood. This effect is reflected by an expanded \( \text{Vo}_2 \) difference. This is a measurement of the difference in the amount of oxygen carried by the arterial and venous blood. A greater \( \text{Vo}_2 \) difference means that more oxygen is being extracted from the blood resulting in lower oxygen concentrations in the venous blood. Maximum cardiac output and \( \text{Vo}_2 \) difference determine maximal oxygen consumption (www.musclementors.com).

Cardio-respiratory fitness refers to the ability of the circulatory and respiratory systems to supply oxygen to skeletal muscles during sustained physical activity. Regular exercise makes these systems more efficient by enlarging the heart muscle, enabling more blood to be pumped with each stroke, and increasing the number of small arteries in trained skeletal muscles, which supply more blood to working muscles. Exercise improves the respiratory system by increasing the amount of oxygen that is inhaled and distributed to body tissue. Cardio-respiratory fitness is also sometimes referred to as Aerobic fitness. There are many benefits of cardio-respiratory fitness. It can reduce the risk of heart disease, lung cancer, type 2 diabetes, stroke, and other diseases. Cardio-respiratory fitness helps improve lung and heart condition, and increases feelings of wellbeing.

To improve the cardio-respiratory fitness we can performing any type of prolonged exercise that recruits our aerobic energy system. Any exercise activity that gets heart rate up and keeps it up for a prolonged period of time qualifies as legitimate cardio-respiratory exercise and is beneficial for aerobic fitness. However, to achieve optimal results from cardio-respiratory fitness training, trainers should select activity type, intensity, frequency and duration of the training.
1.6. **VO$_2$ MAX**

VO$_2$ max (also maximal oxygen consumption, maximal oxygen uptake or aerobic capacity) is the maximum capacity of an individual's body to transport and utilize oxygen during exercise, which reflects the physical fitness of the individual. The name is derived from V - volume per time, O$_2$ - oxygen, max - maximum.

VO$_2$ max is expressed either as an absolute rate in liters of oxygen per minute (l/min) or as a relative rate in millilitres of oxygen per kilogram of bodyweight per minute (ml/kg/min), the latter expression is often used to compare the performance of endurance sports athletes.

“Maximal oxygen uptake (VO$_2$max) is widely accepted as the single best measure of cardiovascular fitness and maximal aerobic power. Absolute values of VO$_2$max are typically 40-60% higher in men than in women (Donna, 1974).” Clearly, then, VO$_2$max varies considerably in the population, with sex being a primary determining factor in this variability.

1.7. **VITAL CAPACITY**

Vital capacity is the maximum amount of air a person can expel from the lungs after a maximum inspiration. It is equal to the inspiratory reserve volume plus the tidal volume plus the expiratory reserve volume. A person's vital capacity can be measured by a spirometer which can be a wet or regular spirometer. In combination with other physiological measurements, the vital capacity can help make a diagnosis of underlying lung disease. The unit that is used to determine this vital capacity is millilitres (ml). A normal adult has a vital capacity between 3 and 5 litres. After the age of 20 the vital capacity decreases approximately 250 cc per ten years.
1.8. AGILITY

Agility means changing direction at speed. Running a 100 metre race does not require agility but doing a floor work exercise in gymnastics does. Imagine a gymnast performing flic-flacs and somersaults they will need to be very agile. A rugby player running for the try line needs agility to dodge a defender who is trying to tackle him. Also Kabaddi, Kho-Kho and Basketball players need agility to tackle the opponents.

1.9. REACTION TIME

Reaction time is the ability to respond quickly to a stimulus. It is important in many sports and day-to-day activities, though it is not often measured. Simple reaction time is the time taken between a stimulus and movement e.g. sprint start. Such simple reaction time depends on nerve connections and signal pathways, is 'hard wired' in the body composition and cannot be improved. Another type of reaction time, choice reaction time, is the time taken between stimulus and action that requires a choice. Choice reaction time can be improved by practice and training.

Performers receive stimuli from the eyes (position of other players, the ball etc), the ears (calling from players, the referee, even spectators), and kinesthetic sense (the performer's position, their options etc). Skilled players reduce reaction time by selecting the most important information, and by anticipating other players’ actions and the path of the ball quickly.

Reaction time is the interval time between the presentation of a stimulus and the initiation of the muscular response to that stimulus. A primary factor affecting a response is the number of possible stimuli, each requiring their own response, that are presented. Hick (1952) discovered that the reaction time increases proportionally to the number of
possible responses until a point at which the response time remains constant despite the increases in possible responses.

1.10. NEED OF THE STUDY

The plyometric and resistance training programmes have become highly structured training for sports performance enhancement. It has vastly different training effects depending upon the intensity and duration of the work and rest period. More research is required concerning the variation in different methods of plyometric training and resistance training and its effects. The applicability of this method of training to develop physical fitness, bio-motor abilities and physiological parameters are not yet completely known. Hence, there is a need to find out whether plyometric training and resistance training are helpful in improving the selected physical fitness, bio-motor abilities and physiological parameters of school athletes. Therefore, there is a need to have ideal properties of plyometric training and resistance training workouts for school athletes in India. Applying these ideas, an attempt has been made to find out the most suitable ratio of plyometric training and resistance training to develop the physical fitness, bio-motor abilities and physiological parameters of school athletes. Being a trainer of school athletes, it was natural for the researcher to take up the interesting study on the effect of a plyometric and resistance training programme on selected physical physiological and bio-motor variables among school athletes.

1.11. STATEMENT OF THE PROBLEM

To find out the effect of plyometric and resistance training on selected physical physiological and biomotor variables among school athletes.
1.12. DELIMITATIONS

The study was delimited to the following factors.

1. To achieve the purpose of the study, forty-five school athletes from Campion Anglo-Indian Higher Secondary School, Tiruchirappalli, Tamilnadu, were selected as subjects.
2. The age of the subjects ranged from 15 to 17 years and all the subjects were healthy and normal.
3. The selected subjects (N=45) were classified into three groups of fifteen each (n = 15) at random. Group I underwent plyometric training, group II underwent resistance training and group III acted as control.
4. The duration of the training period was restricted to twelve weeks and the number of sessions per week was confined to three days, which was considered adequate for selected criterion parameters.
5. The following physical fitness variables namely: speed, leg strength and cardio-respiratory endurance were selected as criterion variables for the study.
6. The selected physiological variables such as VO$_2$ max and vital capacity were selected as criterion variables for the study.
7. The selected bio-motor variables such as agility and reaction time were selected as criterion variables for the study.
8. The data will be collected at prior to and immediately after the experimental period.
1.13. LIMITATIONS

The following uncontrollable factors associated with the study were considered as limitations of the study.

1. The changes in climate conditions (atmospheric temperature, relative humidity, wind velocity and other meteorological factors) during the period of experimentation and at the time of testing were considered as limitations.

2. The growth and development of the subjects if any, during the period of experimentation and the possible influence on the criterion variables could not be controlled. However, the control group was involved to nullify the effect of anatomical and physiological maturation.

3. Though the subjects were motivated verbally, no attempt was made to differentiate the motivation level during the period of training and testing.

4. The quantum of physical exertion, life style and physiological and psychological stress and other factors that affect the metabolic functions were also considered as limitations.

1.14. HYPOTHESIS

Based on the related literature available in the area, the investigator formulated the following hypothesis.

1. There would be a significant difference among the training groups and control group on selected physical fitness variables namely: speed, leg strength and cardio-respiratory endurance.

2. There would be significant improvement between experimental groups and control group on selected physiological variables such as VO\textsubscript{2}max and vital capacity.
3. There would be significant improvement between experimental groups and control group on selected bio-motor variables such as agility and reaction time.

1.15. OPERATIONAL DEFINITIONS

1.15.1. Sports Training

Training is a pedagogical process, based on scientific principles, aiming at preparing sports men for higher performance in sports competitions (Singh, 1991).

1.15.2. Plyometric Training

Plyometrics, also known as "jump training" or "plyos", are exercises in which muscles exert maximum force in short intervals of time, with the goal of increasing power (speed-strength).

1.15.3. Resistance Training

Resistance training is a systematic program of exercises against some resistance for the development of the muscular system. Resistance training program can be designed for a variety of purposes such as weight lifting (Olympic sport), Power lifting, body building, rehabilitation and general muscular conditioning by altering the intensity, duration and frequency (Heyward, 1984).

1.15.4. Speed

Speed is the ability to make rapid movement at the shortest possible time (Singh, 1991).
1.15.5. Strength

Strength is the maximal amount of force a muscle or muscle group can generate in a specified movement pattern at a specified velocity of movement (Steven and William, 1997).

1.15.6. Leg Strength

Leg strength is the capacity of the lower limb to exert muscular force (Ted and Andrew, 1987).

1.15.7. Cardio-Respiratory Endurance

This is the quality that enables one to continue engaging in reasonably vigorous physical activities for extended periods of time and where the required cardio-respiratory adjustments to the activity is built up (Uppal, 2000).

1.15.8. VO$_2$ Max

It is the maximal capacity for oxygen consumption by the body during maximal exertion. It is also known as aerobic power, maximal oxygen consumption, and cardio-respiratory endurance capacity (Wilmore & Costill, 1994).

1.15.9. Vital Capacity

The maximal volume of air expelled from the lungs after maximal inhalation (Wilmore & Costill, 1999).

1.15.10. Agility

Agility is the ability to change the direction of the body in an efficient and effective manner (Prentice, 1994).
1.15.11. Reaction Time

Time elapsed from the presentation of a stimulus until the initiation of a response.

1.16. SIGNIFICANCE OF THE STUDY

Each athlete will have different physical, physiological and bio-motor abilities and the interest to undergo a particular training method which may also vary. Since, there is enough alternative training methods, a coach could easily choose the best one which suits for their athlete’s training. This study can contribute in the following ways.

1. The result of the study will help the coaches to identify the appropriate methods among the plyometric and resistance training confined to this study in improving the physical, physiological and bio-motor variables.

2. The result of this study will be helpful to physical education teachers and coaches in designing the plyometric and resistance training programs to improve player’s performance according to the individual concerned.

3. The results of this study reveal the extent to which the chosen physical, physiological and bio-motor variables would change due to plyometric and resistance training programme for twelve weeks.

4. This attempt would give impetus to researchers to analyze various aspects related to plyometric and resistance training.

5. The outcome of the study may add a little more to the ocean of knowledge in the area of sports training.