Chapter I
INTRODUCTION

Theories and methods of training have existed since time immemorial. One can find mention of these in the history of mankind. The Egyptians, Greek, Roman, Chinese, Indian and other ancient civilizations used special methods of physical preparations for training their soldiers and sportsmen. Some basic principles of training like continuity, progression of load, specificity were recognized and widely practiced in ancient times. But these theories and methods were generally for the physical preparation only. A distinct science of sports training however did not come into existence till the latter half of the twentieth century (Hardayal Singh, 1991).  

Today through training, as in ancient times, the athlete prepares himself/herself for a definite goal. In physiological terms, the goal is to improve the body’s system and functions in order to optimize athletic performance. Training is planned and organized by a coach, whose role among many others, is that of an educator whose task is very complex since he/she deals with many physiological, psychological and sociological variables. Above everything, training is a planned and systematic process progressively given for a long duration in which individuals are graded. Training aims at moulding the human’s psychological and physiological functions in order to meet demanding task.

The relationship between physical activity and health gives physical educators, exercise scientists, and sport leaders the opportunity to make a significant contribution to the health of the nation and to the lives of individuals with whom they work. Physical activity has been associated with a myriad of health benefits. Physical activity can increase longevity; a significant twenty to thirty percentage of reduction in all causes of mortality associated with adherence to recommended physical activity guidelines for health. The saying ‘Health is Wealth’ emphasizes the importance of fitness in day to day life. Physical activity has a nexus with both physiological and psychosocial benefits. Students should be motivated to involve themselves in physical activity to develop their musculoskeletal and cardiovascular health. The adaptation of the human body to physical exercise through various sports activities can improve the
health of internal system and the efficiency of external movements, such an adaptation to one kind of stress may also prepare the person physically and emotionally to resist other stresses in life. (Wuest, 2010) ²

The physical fitness or condition is the sum total of five motor abilities namely strength, speed, endurance, flexibility and coordinative abilities. These five motor abilities and their complex forms are the basic requirement for human motor actions. Therefore, performance in all sports depends to a great extent on these abilities. Systematic training imparts certain changes both structurally and physiologically in the body. The level of adaptation is directly proportional to the volume, frequency and intensity of training. Training imparted to athletes, influence the body and make it fit for adaptation to stress of physical work. Too much of training will have a negative impact on the body threshold level. (Bompa, 1999) ³

Muscular strength, muscular endurance and speed are also important to good health. Millions of people suffer from problems with low-back pain. Many of these problems can be attributed to muscular weakness and imbalance, which in turn can be attributed to inactivity or participation in inappropriate activities. Millions of elderly people and individuals with disabilities may have trouble in performing tasks of daily living because of insufficient development of these fitness components. Regular and appropriate physical activity can help these individuals achieve functional independence. Reduced risk of muscle and joint injury is also a positive outcome of regular and appropriate activity. (Wuest, 2010) ⁴

Physiological variables may be defined as the scales that measure the function of human systems. In human being a variety of physiological functions such as heart rate, breath holding time, vital capacity and VO₂ max show distinct changes in the course of training, with the values falling to their lowest during rest. This phenomenon is accepted only in sports field. These changes in physiological functions have been found to be associated with changes in performance.

Enhanced cardiovascular function is one health benefit of physical activity. This helps to reduce the risk of heart disease. Resistance to atherosclerosis is
improved as desirable serum cholesterol levels are maintained, low-density lipids are reduced and protective high density lipids are increased. Thus, the risk of a heart attack is lessened, and the chances of surviving a heart attack were increased. Physical activity can also help reduce other risk factors associated with cardiovascular disease such as obesity and hypertension. (Wuest, 2010)

Blood stream carries the main forms of fat called cholesterol and triglycerides. These fats are lipids come partly from food, partly from the body’s own production in the liver. Fats are not water soluble and hence cannot travel through the blood easily. With the help of lipoprotein, digested fat from the liver is carried to various parts of the body by the blood vessels. The cholesterol returns to the liver and repeats its job.

The lipoproteins are packages of cholesterol placed in liver. Lipoproteins are made from lipids and proteins. There are mainly four kinds of lipoprotein packages namely chylomicrons, very low density of lipoprotein (VLDL), low density of lipoprotein (LDL), high density of lipoprotein (HDL). High density of lipoprotein has more protein content (Srilakshmi, 2005)

Physical activity can help maintain a desirable body composition. Excessive body fat is hazardous to one’s health and it can shorten one’s life. Elevated serum cholesterol levels, diabetes, hypertension, gallbladder disease, cardiovascular distension, osteoarthritis of the weight-bearing joints and some type of cancer are all associated with being overweight. Additionally, many adults and children who are obese experience psychological stress and self concept problems. Physically active on a regular basis helps to maintain a healthy body composition by using excess calories and by preventing the addition of undesirable weight thus reducing susceptibility to disease. Physical activity also can contribute to improved physical appearance and self-image. (Wuest, 2010)
RESISTANCE TRAINING

Resistance training is an improved method of physical conditioning which uses various types of resistive loads like weight plates, medicine balls which ensures good muscular fitness to present day youth. The impact of resistance training has been widely accepted by medical and fitness organizations in the global scenario. It has multifaceted advantages viz., to strengthen bones, improving or stabilizing weight, changing the psychosocial wellbeing and in reducing risk of cardiovascular related problems. Resistance training plays a pivotal role in improving the general health and fitness of people; hence more focus has to be given in the near future. Resistance training has become popular in recent times especially in improving the health of population.

The training and development of the body by using gadgets was first observed in Britain around the start of the twentieth century. But it is only in the past few years that sports coaches have observed weight training as a useful aid to a sports person’s development. Athletics and swimming were the first two sports to utilize weight training techniques for its competitors but now almost every sport has incorporate some form of weight training programme into their training manuals.

Resistance training has been recommended by national health organizations to be included in fitness programmes which include aerobic and flexibility exercise. Resistance training has numerous uses; it increases basal metabolic rate, increase muscle and connective tissue cross sectional area reduced cholesterol, improves blood lipid profile, decreases blood pressure, glucose tolerance, improves insulin sensitivity, improves functional capacity and relieves low back pain. The key element to resistance training lies in supervision by qualified professional and the proper usage of the program variables. (Kraemer et al, 2002)  

Resistance training has its own pros and cons. The desirable qualities alone should be called out and should be thrust on youngsters for the betterment of life. Certain guidelines should be framed in highlighting the safety of resistance training. Subjects may perform better and become stronger with appropriate training. Increased strength gets reflected in various activities where strength, power or speed is essential.
The primary objective in strength training is not to learn to lift as much weight as possible, but to increase strength. This is possible only when the coaches and physical education teachers use the correct and most beneficial and economical means to train their trainees. *(Uppal, 1984)*

**RESISTANCE TRAINING METHODS**

Muscular fitness can be improved using various types of resistance training *viz.*, static (isometric), dynamic (concentric and eccentric) and isokinetic methods. Although there are general guidelines for designing static, dynamic and isokinetic resistance training programs, each exercise prescription should be individualized to meet the specific needs and goals of the trainee.

**Static (Isometric) Training method**

In this method, tension is developed in the muscle working against resistance but there is no change in the length of the muscle. The literal meaning of the word isometric is constant length i.e., iso means constant and metric means length. The reason why the muscle does not shorten in this contraction is because the external resistance against which the muscle is pulling is much higher than the maximum tension (internal force) the muscle can produce. *(Uppal, 2009)*

Static exercise is contraindicated for coronary prone and hypertensive individuals because the static contraction may produce large increases in intra-thoracic pressure. This reduces the venous return to the heart, increases the work of the heart and causes a substantial rise in blood pressure.

**Isokinetic Training method**

This procedure involves development of maximum tension in the muscle, which shortens at constant speed at all angles over the full range of motion.

For performing isokinetic exercises, special isokinetic machines are required. These machines have a speed governor so that the speed of movement is constant, no matter how much tension is created in the muscle. Therefore, in this method when quick movements are done, the muscle generates maximum tension throughout the
entire range of motion, but the speed of movement will be constant. The special feature of the isokinetic machine is called “accommodating resistance”. Isokinetic method is considered to be the best for improving muscular strength and endurance for sports. (Uppal, 2009)¹¹

Isokinetic training is used to increase strength, power and muscular endurance which combines the advantages of both dynamic (full range of motion) and static (maximum force executed) exercise. Isokinetic training feature keeps overcoming the problems associated with using either a constant or variable resistance exercise mode. Isokinetic training involves dynamic, shortening counteractions of the muscle group against an accommodating resistance that matches the force produced by the muscle group to the entire range of motion. A device can be used to control the speed of movement. Exercise may be done using a partner who offers accommodating resistance to the movement, but the speed cannot be precisely controlled.

Dynamic Resistance Training Methods

In this method, the muscle shortens with varying tension while lifting a constant load. The literal meaning of the word isotonic is constant tension i.e., iso means constant and tonic means tension. Keeping this meaning in mind, the contraction is expected to produce same amount of tension while contracting as it overcomes same resistance throughout the entire range of movement. But this is not true, because the tension produced in the muscle as it shortens is affected by the following three factors.

- Initial length of the muscle fibres
- Angle of pull of the muscle
- Speed of contraction

In this contraction, the muscle lengthens while contracting (developing tension) i.e., both the origin and insertion on the muscle move away while the muscle is contracting. This contraction can be best explained with the example of elbow flexion against resistance. Flex your elbow and have someone trying to extend your forearm by pulling down on your wrist. At the same time, resist the pull by attempting to flex your elbow. As your forearm is extended, the elbow flexor muscle will lengthen while contracting.
In our normal usage, eccentric contractions are based, in countering the effect of gravity *i.e.*, while walking down the hill or stairs. In sports, it is used in activities like wrestling where one competitor resists the effort of the other to forcefully move the arm or the leg but ultimately loses out in the struggle. *(Uppal, 2009)*

**DEVELOPING RESISTANCE TRAINING PROGRAMS**

Physiological knowledge from the field of exercise offers guidelines for professionals to use when planning a resistance training programs to improve fitness. Training principles should be followed wherever the exercise program is being designed by an elementary school physical educator to improve students’ health fitness, by a coach to improve athletes’ performance, by an exercise leader to enhance adults’ fitness, or by an exercise specialist as part of a patient’s cardiac rehabilitation program. Several physiological and behavioural factors must be taken into account if the sought-after benefit improvement and maintenance of fitness are to be realized when designing a resistance training program. Before designing a resistance training program for a trainee, training principles have to be reviewed and also determine how each of these principles can be incorporated into the trainees’ program. *(Heyward, 2006)*

**Principle of overload**

To gain improvements in health and fitness, overload is essential. Simply stated, if improvements are to occur, one must perform more than one’s normal amount of exercise. An increased demand or workload must be placed on the body for benefits to occur. The body’s adaptation to this increased workload leads to changes in fitness levels. For example, if improvement in muscular strength is the goal, the muscles must be exercised with a greater weight than normal.

**Principle of specificity**

The kinds of physiological changes that occur as a result of training are related to the type of training employed. Therefore, training programs should be designed and overload applied with specific goals in mind. Overload is specific to each fitness component. For example, stretching exercises will have little impact on cardiorespiratory fitness. Furthermore, overload is specific to each part of the body.
Strengthening the legs builds fitness in the legs, not in the arms. Professionals must understand fitness goals, sport demands and design fitness programs specifically to achieve these aims. *(Heyward, 2006)*

**Principle of progression**

Overload should be applied gradually and steadily increased for best results. As the body adapts to the overload, the overload should be systematically increased by altering the frequency, duration, or intensity of the exercise. An individual training to gain cardiorespiratory endurance may begin an exercise program by jogging two miles at a moderate intensity. The next week the individual would increase the distance to two and a half miles while still working at the same level of intensity. Week after week, the overload would be adjusted until the desired level of fitness is attained. Programs should be carefully monitored so that the individual is challenged by the workout but not overwhelmed. *(Uppal, 1984)*

**Principle of variation**

There were many different ways to achieve desired fitness goals, including variation into a training program by maintaining individuals’ interest and providing a change of pace while still making progress towards desired goals. Variation helps alleviate boredom and overcome plateaus or periods where there seems to be little progress. Manipulating the intensity of exercise, its duration, or its type can introduce variability into the program. Alternating hard workouts with easier workouts or running in different locations within the community are few ways to introduce variability into the individual’s fitness program.

**Additional Principles**

Individuals with lower initial strength will show greater relative gains and a faster rate of improvement in response to resistance training, than those starting out with higher strength levels (principles of initial values and inter-individual variability). Further, when the individual stops resistance training, the physiological adaptations and improvements in muscle structure and functions are reversed (principle of reversibility). Using periodization techniques we can lessen the effects of detraining on athletes and maintain strength gains during the competitive period by manipulating the intensity and volume of the resistance training exercise. *(Heyward, 2006)*
FACTORS INFLUENCING RESISTANCE TRAINING

There are many variables which describe a resistance training program, in which the principle variables are training intensity and volume. Specifically by manipulating training intensity, training volume and other variables, the wholesome development of an individual can be enhanced. Training intensity and training volume plays a vital role while designing a resistance training program.

The correlation between training volume and intensity has its own merits and demerits. High intensity combined with low volume training is acceptable, only for a stimulated period of time though it increases muscular strength under resistance training, whereas aerobic capacity does not improve. It was vice-versa under low intensity and high volume training. The volume of training to be imposed has its own limitations over training which can lead to stress, resulting in utter failure to achieve the goal. Therefore, efforts are made by physiologists to determine the maximal and minimal stimuli needed for cardiovascular activity and improvement of muscles in human being.

Training Intensity

Intensity is an important component of training. It is the qualitative work that an athlete performs in a given time. More the work performed by an athlete per unit of time, higher will be the intensity. Intensity is a function of the strength of the nerve impulses that the athlete employs in training. Intensity, along with the volume and density, is one of the most important components of training. It refers to the qualitative component of work performed in a given period in time. In strength training, intensity is expressed as a percentage of load or one repetition maximum (1RM). (Mathews and Fox, 1981)\(^7\)

It represents the degree of effort made by the sportsperson while performing an exercise. The degree of effort is always considered in relation to time and is equated with the amount of force or energy spent in relation to time. It is divided into intensity of stimulus (load intensity) and density of stimulus (load density). (Uppal, 2009)\(^8\)
Training Volume

Volume is a prime component of training and is the quantitative prerequisite for high technical, tactical and physical achievements. The volume of training, sometimes inaccurately called as the duration of training includes the following integral parts

- The time or duration of training.
- Distance covered or weight lifted per unit of time.
- The repetitions of an exercise or technical element an athlete performs in a given time.

Volume implies the total quantity of activity performed in training. Volume also refers to the sum of work performed during a training lesson or phase. When you refer to the volume of a training phase, it means that it is the sum of the repetitions performed during each training session multiplied by the resistance used (Kraemer et al., 2002). Throughout the resistance training program, volume and intensity must be systematically increased (progression principle) to avoid plateaus and to ensure continued strength improvements. The training volume may be altered by changing the number of exercises performed for each session, the number of repetitions performed for each set, or the number of sets performed for each exercise. Several models of periodized training can be used to systematically vary the volume and intensity.

Set

Traditionally, a set refers to the number of sets performed for a specific muscle group which is a better indicator of training stress than sets per exercise. The optimal number of sets for improving muscular strength is controversial and depends on the trainee’s goal, one to two sets for children and older adults and one to three sets for novice and intermediate lifters are recommended (Kraemer et al., 2002). Some studies suggest that single sets (one set per exercise) are just as effective as multiple sets (two to three sets per exercise) for increasing the strength of untrained and recreational lifters during the first three to four months of resistance training (Feigenbaum and Pollock, 1999). A major advantage of single-set programs is that
they require much less time for a training session than do multiple-set programs (twenty versus fifty minutes), potentially increasing the trainee’s compliance. The ACSM (2006) recommends prescribing one set performed to the point of fatigue for each exercise.

However, the results of a recent meta-analysis of one forty strength training studies do not support prescribing single-set programs to develop the strength of untrained and trained recreational lifters (Rhea et al., 2003). Using this definition of sets, it is reported that an average of four sets during each training session optimizes strength development in untrained and trained lifters. For single-set programs, the authors suggest prescribing multiple exercises for a specific muscle group in order to reach the goal of four sets.

One can use either a single set or multiple sets of exercise. For multiple sets, one may choose to have the trainee consecutively perform a designated number of sets (usually three or more) at a constant intensity e.g., 10-RM for each exercise. Alternatively, you may have your trainee perform one set of three different exercises for the same muscle group. For example, instead of three consecutive sets of barbell curls for the elbow flexors, coach may prescribe one set of incline dumbbell curls, one set hammer curls, and one set of barbell curls. This adds variety to the program and changes the training stimulus since different muscles or parts of a muscle are used to perform each of these exercises.

A trainee performing multiple sets of a given exercise may choose to lift the same weight for each set or to vary the intensity of each set by lifting progressively heavier (light to heavy sets) or lighter (heavy to light sets) weights. Pyramiding is a light to heavy system in which the trainee performs as many as six sets of each exercise. In the first set, the trainee lifts a relatively lighter weight for ten to twenty repetitions (10 to 12 RM). In subsequent sets the individual lifts progressively heavier weights (i.e., 8-RM, 6-RM, and 4-RM). Since this involves such a large volume of work, trainer should prescribe the pyramid system for experienced weightlifters only. Bodybuilders commonly use this system to develop muscle size.
Multiple sets using periodization are recommended for serious athletes, power lifters and bodybuilders engaged in advanced strength training and hypertrophy programs (Kraemer et al., 2002). To optimize the strength gains of collegiate and professional athletes, an average of 8 sets per muscle group is recommended. (Peterson et al., 2004)

**Frequency**

Muscular fitness may improve from exercising just one day per week, especially in trainees with below-average muscular fitness. Recent research, however, suggests that the optimal frequency of strength training for untrained individuals is three days per week. For healthy populations, the ACSM (2006) recommends two to three non-consecutive days per week. For advanced lifters, four to six training sessions are recommended. (Kraemer et al., 2002)

Traditionally for advanced resistance training programs, experts have recommended resistance training three times per week on alternate days (e.g., M-W-F) to allow time for the muscles to recover. For individuals who want resistance training four to six days per week, a split routine was prescribed. With a split routine different muscle groups are targeted on consecutive days, thereby allowing at least one day of recovery for each muscle group. For example, a bodybuilder may exercise the chest and shoulders on Monday and Thursday, the hips and legs on Tuesday and Friday, and the back and arms on Wednesday and Saturday.

To optimize the strength gains of trained recreational lifters and competitive athletes, each muscle group should be exercised twice a week (Peterson et al., 2004). Advanced lifters and competitive athletes who train four to six days per week can accomplish this goal by using split routine. A rest of forty eight hours between workouts should be allowed for muscles to recuperate and to prevent injury from overtraining.

**Order and Number of Exercises**

Exercise scientists generally recommend ordering the exercises so that large muscle groups are exercised at the beginning of the workout with progression to smaller muscle groups later in the workout. To maximize the overload of muscle groups, however, some trainees may choose to pre-exhaust muscle groups by
reversing this order. To do this, the individual fatigues smaller muscles by using single-joint exercises prior to performing multijoint exercises.

When two or more exercises were prescribed for a specific muscle group, the individuals should be instructed to alternate the muscle groups so that the muscle can rest and recover between exercises. For example, trainees should not perform leg press and leg extension exercises consecutively because the quadriceps femoris is used in both of these exercises. Instead, intersperse one or more exercises using different muscle groups between these two exercises.

Some research suggests that single-set training is as effective as multiple-set training for increasing the strength of untrained individuals during the initial stage of resistance training. For long-term training, however, multiple sets elicit greater strength gains for trained men and women (Wolfe, Lemura, and Cole, 2004). For a comprehensive quantitative meta-analysis of studies comparing single and multiple-set programs. (Paulsen, Myklested, and Reestad, 2003) noted that the best method depends on the muscle groups exercised. They reported that multiple sets were superior to single sets for increasing leg strength, whereas both were equally effective for increasing the upper-body strength of untrained men during the initial phase (6 wk) of training.

The basic method of training has not changed much but the development was more on intelligent science based systems that involve higher quality and regular and prolonged application of volume, intensity and density which mainly affect the demand that the athletes encounter in training, although these three components may complement each other, an increased emphasis on one may cause an increased demand on the athletes. For instance, if the coach intends to maintain the same demand in training, and the needs of the sport require developing endurance, then he or she must increase volume. The coach then has to decide how this will affect density and how much to decrease intensity. If the coach decides to evaluate overall demand in training by varying intensity, then he or she needs to forecast how this new situation will affect the volume or density of training. The planning and direction in training is a function of the three main components. The coach must guide the
evolution of the curve of these components, especially volume and intensity, in direct relationship with the athlete’s index of adaptation, phase of training and the competition schedule. Furthermore, in the science of knitting the training components may facilitate a correct peaking for the main competition (Bompa, 1999).

DESIGNING RESISTANCE TRAINING PROGRAM

The training program needs to be individualized. By varying the combination of intensity, duration and frequency of exercise, one can develop programs that meet the unique goals and needs of each trainee. Proper guidelines and recommendations for resistance training programs, as well as specific recommendations and precautions are to be followed when developing resistance training programs. ACSM (2006) has summarized guidelines for the resistance training of healthy populations.

During the first eight weeks of training, use minimal resistance for all exercises. Instruct about proper weightlifting and breathing techniques. Trained exercise leaders who have experience should closely supervise and monitor the trainee’s weightlifting techniques and resistance training program during the first few exercise sessions. Prescribe multi-joint, rather than single-joint, exercises. Use exercise machines to stabilize body position and control the range of joint motion. Avoid using free weights at initial stages. Each exercise session should be approximately twenty to thirty minutes and should never exceed sixty minutes. Prescribe one set of ten to fifteen repetitions for eight to ten different exercises for the major muscle groups. Allow at least forty eight hours of rest between the exercise workouts. Discourage trainees with joint pain or inflammation. When trainees are returning to resistance training following a layoff of more than three weeks, they should start with a low resistance that is less than fifty percent of the weight they were lifting prior to the lay off.

The ACSM (2006) recommends moderate intensity (RPE=23-13) exercise to improve the muscular fitness of older adults; prescribe one set of ten to fifteen repetitions for eight to ten different exercises. Vincent and colleagues (2002) noted long term (6 Months) improvements in the strength and muscular endurance of older adults (60-83 years) who participated in either a low intensity (1 set at 50% 1-RM) or
a high intensity (1 set at 80% 1-RM) resistance training program three days per week likewise, Hunter and colleagues (2001) reported that isometric and dynamic muscle strength gains are similar for older adults (>60 years) engaging in either a non periodized, high-intensity program (2 sets at 80% 1-RM, 3 days per weeks) or an undulating periodized (UP) program varying training volume each day (2 sets at 50%, 65%, or 80% 1-RM, 3 days per week). Some evidence suggests that training for one, two or three days a week at eighty percent of one repetition maximum produces similar strength gains in older (65-79 years) men and women (Taaffe et al., 1999) 26.

The optimal training stimulus for developing muscular strength or endurance is controversial. Some research supports the conventional prescription of high intensity-low repetition resistance exercise for strength development and low intensity-high repetition exercise for muscular endurance (Kraemer and Ratamess, 2004) 27. Contrary to this traditional approach, the ACSM (2006) supports the position that muscular strength and endurance develop simultaneously over a wide range of repetitions (3 to 20) provided that the resistance exercise (whether 3 to 6, 9 to 12, or 12 to 15 repetitions) is performed at a high intensity (i.e., to the point of muscular fatigue or failure). To develop the strength and muscular endurance of healthy individuals, the ACSM (2006) recommends eight to twelve repetitions performed at high intensity.

The mean optimal intensity for developing strength ranges between sixty percentages and sixty percentage of one repetition maximum. At these intensities, most individuals are able to perform one to twelve repetitions (1-RM to 12-RM). The trainee’s experience with resistance training dictates the optimal intensity for developing strength. Generally, one should prescribe intensities of sixty to seventy percentages of one repetition maximum for novice lifters, and seventy to eighty percentages of one repetition maximum for advanced lifters. Recent meta-analyses support these recommendations. (Rhea et al., 2003) 28 reported that the optimal intensity for strength gains in untrained (<1 years) lifters differs (60% 1-RM and 80% 1-RM, respectively) and for competitive athletes (college and professional), the optimal training intensity is eighty five percentage of one repetition maximum (Peterson, Rhea, and Alvar 2004) 29 keeping in mind that these intensities are averages. Throughout the strength training program, intensity needs to be varied for continued improvement.
Although this training stimulus may be sufficient for beginner and novice lifters, experts recommend that, resistance training programs be tailored to the specific goals of intermediate and advanced lifters (Kraemer and Ratamess, 2004). It is possible to design programs to optimize the development of muscle strength, size (hypertrophy), endurance or power by varying the intensity repetitions, sets, and frequency of training.

**TABLE I**

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Rest Period</th>
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<tr>
<td>&gt;13-RM ~ &lt;65% 1-RM</td>
<td>&lt;1 min</td>
</tr>
<tr>
<td>11-RM to 13-RM ~ 65 to 74% 1-RM</td>
<td>1-2 min</td>
</tr>
<tr>
<td>8-RM to 10-RM ~ 75 to 80% 1-RM</td>
<td>2-3 min</td>
</tr>
<tr>
<td>5-RM to 7-RM ~ 76 to 87% 1-RM</td>
<td>3-5 min</td>
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**EFFECTS OF RESISTANCE TRAINING**

Resistance training provides many health benefits, especially for adults. In addition to increasing strength and muscular endurance, resistance training may improve the performance of functional tasks such as lifting and reaching, rising from the floor or a chair to a standing position, stair-climbing, and walking. Resistance training leads to morphological adaptations in skeletal muscles and bone. A structural change in muscle fibers accounts for a large portion of the strength gains. Increases in bone mineral content and bone density improve bone health. The important effect of resistance training is an increase in the size of the muscle tissue. This adaptation, known as exercise-induced hypertrophy, is due to increase in the total amount of contractile protein, the number and size of myofibrils per fiber, and the amount of connective tissue surrounding the muscle fibers (Goldberg et al., 1975).

Heavy resistance training has been reported to produce an increase in the number of muscle fibers (i.e., hyperplasia) in animals due to longitudinal splitting and satellite cell proliferation (Antonio and Gonyea 1993; Edgerton 1970; Gonyea, Ericson, and Bonde-petersen 1977). Such processes, however, have not been clearly demonstrated in human skeletal muscle tissue. Although some data suggest that human skeletal muscle has the potential to increase muscle fiber number,
hyperplasia probably contributes less than five percentages to overall muscle growth in response to heavy resistance training. The major factor contributing to exercise-induced hypertrophy for humans apparently is an increase in the size of existing muscle fibers.

Muscle strength is directly related to the cross-sectional area of the muscle tissue. (Ilkai and Fukunaga, 1968) indicated that the static strength per unit of cross-sectional area of the elbow flexors was similar for young men and women. These values ranged between 4.5 and 8.9 kg/cm²; average values were 6.2 and 6.7 kg/cm² for women and men, respectively. (Cureton et al., 1988) also reported that the dynamic strength per unit of cross-sectional area (CSA) was similar for men and women. Post training ratios of elbow flexor/extensor strength to upper arm CSA were 1.65kg/cm² and 1.85kg/cm² respectively, for men and women. Likewise, the post training ratios for leg strength to thigh CSA were 1.10kg/cm² for men and 0.90kg/cm² for women.

In the past, it was believed that resistance training produced less muscle hypertrophy in women than in men even though their relative strength gains were similar, but muscle hypertrophy was assessed indirectly using anthropometric and body composition measures. (Cureton et al., 1988) however, using computerized tomography to directly assess muscle hypertrophy in a heavy resistance training program (70% to 90% 1-RM, 3 days/wk for 16 wk), found significant increases in CSA of the upper arms of women (5 cm² or 23%) as well as men (7 cm² or 15%). Although the absolute change was slightly larger in men, the relative degree of hypertrophy was similar for men and women.

Today experts agree that the relative increases in fiber size are similar for women and men when the training stimulus is the same (Deschenes and Kraemer, 2002). In addition, periodized resistance training is particularly effective for increasing muscle size in women. (Kraemer and colleagues 2004) recently compared the effects of total and upper-body periodized training programs on muscle hypertrophy in young women. Over six months of training, the total-body periodized program produced greater and more consistent gains in overall (upper and lower body) muscle size compared to upper-body periodized training. An intensity range of three
to eight repetition maximum produced greater muscle hypertrophy than did a range of eight to twelve repetition maximum.

Exercise-induced hypertrophy appears to be an important mechanism underlying strength gains in older women and men. This implies that older adults can effectively counter age-related loss in muscle by participating in a vigorous resistance training program.

The main components which influence the physical performance of an athlete are strength, speed, agility, endurance, power and coordinative abilities. Action potential depends on the natural abilities and fundamental abilities which serve the foundation for excellence (Fox, 1984).

The development of strength and associated power has almost certainly been one of the greatest factors to enhance modern sport techniques and performance. But, it is not a new concern. Theories of the past reveal that when Milo reputedly carried a bull calf everyday from the day it was born until it was fully grown. As the bull grew and became heavier Milo’s strength levels improved to compensate in a form of early progressive resistance training (Paish, 1998).

Strength gained will not assure success in any sport. It is usable strength that is the key, the strength which can be applied to the body to make it move faster, change speed, change the direction of body movements, exert a greater speed into a club or racket head or make the pull on oar faster and longer. While strength is a dominant factor one must also call upon skill, mobility and speed.

Elastic strength is defined as the ability of the neuromuscular system to overcome resistance with a high speed of contraction (power, fast strength). The neuromuscular system accepts and expels rapid loading at high velocity through the co-ordination of reflexes along with the elastic and contractive components of muscle. The adjective “elastic” is very appropriate and key to avoid confusion between “speed of contraction” and “strength of contraction”. Elastic strength determines performance in all of the so-called “explosive” sports that is jumping, sprinting, striking etc. This is
the capacity of all or part of the organism to maintain strength expression through fatigue. It is characterized by a relatively high application of strength with mental and physical perseverance. Age old tests of “strength”, such as maximum press-ups or holding a weight at arm’s length for longer duration are in fact tests of strength endurance. It determines performance principally when considerable resistance is to be overcome for a fairly long period of time. Thus in rowing, swimming, cross country skiing and track events between sixty seconds and eight minutes duration one would expect to find strength endurance to be a critical factor (Dick, 1992) 42.

Speed is more over a product of nature than nurture. A person is born with muscles capable of working at speed. Some people in sports refer such muscles as “fast twitch”, although the true sports scientists refer them as “fast-glycolytic”. This means at maximum capacity, the muscle fibers use the basic energy-giving substance quickly. Hence their capacity for work of a sustained nature is very limited – probably in the region of thirty to forty seconds for a major muscle group. Fast-acting fibers also have to receive a special nerve impulse which is probably more refined in some people than others, for promoting the natural gift of speed.

While most people involved in sports training accept that, the speed is a quality which is inherent and someone either born with or not, it does not mean that it is not trainable. A person is born with an ultimate speed potential, and only by planned training this potential can be fully realized, although the performer may be encouraged to adapt him/her to achieve the ultimate potential. At any stage in a player’s career he or she must always function with the belief that they can produce faster movements. Indeed, this is a basic philosophy of all involved in sport-the ultimate performance is always “Just around the corner” (Paish, 1991) 43.

Although strength training produces greater hypertrophy in fast-twitch (type II) muscle fibers than in slow-twitch (type I) fibers, there is no evidence to support the conversion of slow-twitch to fast-twitch fibers. Resistance training does not alter the percentage of type I and II muscle fibers. However, heavy resistance training affects the proportion of fibers comprising subgroups of type II muscle fibers, increasing the percentage of type IIB (fast-twitch-glycolytic) muscle fibers while decreasing the
percentage of type IIA (fast-twitch-oxidative) fibers in both men and women (Deschenes and Kraemer, 2002).

Injuries sustained during competitive sport activities are accepted as an inherent part of the game while it may be true that the associated risk of participating in certain sports increases the chance of becoming hurt and it is safe to assume that, many injuries can be avoided if preventive medicine is practiced. Conditioning and strength training go a long way in protecting the athlete from possible harm, but in some cases this is not enough. There are varieties of methods that can be used to enhance muscular strength. These include the use of free weights, pneumatic resistance system, variable resistance machines, heavy eccentric training, isometric training and accommodating resistance training. There are several important factors to be considered when attempting to increase the strength of the muscle. The intensity of the training, in terms of load lifted, appears to be the most important factor for the development of strength. The musculature needs to be progressively loaded above the point to which it has occurred in order to release continued strength gains. The development of strength in response to training decreases as a function of the current level of strength, so that initial strength increase for novice subjects will occur, with almost any training method the strength of muscle is closely related to its size.

Resistance training has beneficial effects on bone health that may decrease the risk of osteoporosis and bone fractures, particularly in women. This form of training may help to achieve the highest possible peak bone mass in premenopausal women and may aid in maintaining and increasing bone in postmenopausal women and older adults. Bone mineral density of the lumbar spine and femur in premenopausal women significantly increased after twelve to eighteen months of strength training. Also, lumbar bone mineral density of early-postmenopausal women was improved following nine months of strength training. However, in a study of older women (65 to 79 Years), twelve months of high-intensity (80% 1-RM) and low intensity (40% 1-RM) resistance training did not significantly improve the bone mineral density of the lumbar spine and hip. Still, evidence suggests that resistance training and higher-intensity weight-bearing activities (not walking) may slow the decline in bone loss even if there is no significant increase in bone mineral density. Improvements in bone
mineral density appear to be site specific the greater changes occur in bones to which the exercising muscles attach. Experts agree that resistance training has a more potent effect on bone health than do weight-bearing aerobic exercises such as walking and jogging (Layne and Nelson, 1999). Resistance training also improves the size and strength of ligaments and tendons (Fleck and Falkel, 1986). These changes may increase joint stability, thereby reducing the risk of sprains and dislocations.

BIOCHEMICAL EFFECTS OF RESISTANCE TRAINING

The morphological changes in skeletal muscles due to resistance training are caused by hormones. This section addresses questions regarding hormonal responses to resistance exercise as well as changes in the metabolic profile of skeletal muscles.

Exercise-induced hypertrophy occurs through hormonal mechanism. Anabolic (protein-building) hormones such as testosterone, growth hormone, and insulin-like growth hormone increase in response to heavy resistance exercise and interact to promote protein synthesis. The magnitude of testosterone and growth hormone releases, however, appears to be related to the size of the muscle groups used, the exercise intensity (%1-RM), and the length of rest between sets, with larger increases observed for high-intensity (5-10-RM) exercise and short (1 min) rest periods involving large muscle groups. In men, high-intensity resistance training produces significant increases in testosterone and growth hormone, but testosterone appears to be the principal muscle-building hormone. Levels of catecholamine (non-epinephrine, epinephrine, and dopamine), which augment the release of testosterone and insulin-like growth factor, also increase in men in response to heavy resistance exercise. In women, growth hormone is likely the most potent muscle-building hormone (Deschenes and Kraemer, 2002).

Although high-intensity resistance training results in substantial increase in muscle proteins, it appears to have little or no effect on muscle substrate stores and enzymes involved with the generation of adenosine tri-phosphate (ATP). Although stores of ATP and creatine phosphate (CP) may increase significantly in response to
strength training, the changes are not large enough to have practical significance. Strength training produces only minor alterations in myosin adenosine triphosphatase activity and other ATP turnover enzymes, such as Creatine Phosphokinase, in response to strength training. Strength training using heavy resistance and explosive exercises results in decreased activities for hexokinase, myofibrillar ATPase, and citrate synthesis.

The mitochondrial volume density following heavy resistance training has been reported to decrease as a consequence of a disproportionate increase of contractile protein in comparison with mitochondria. In theory, this could be detrimental to aerobic capacity and endurance performance. A review of studies of this phenomenon, however, concluded that participation in heavy resistance training does not negatively affect aerobic power (Sale et al., 1987) 48. Also, capillary density has been shown to increase, which in turn enhances the potential to remove lactate produced by the muscles during moderate-intensity, high-volume resistance exercise.

**NEUROLOGICAL EFFECTS OF RESISTANCE TRAINING**

In addition to muscle hypertrophy, neural adaptations significantly contribute to strength gains, especially during the initial stages of resistance. This section addresses questions regarding neural adaptations to short- and long-term resistance training. Electromyographic evidence led Moritani and DeVries to conclude that increased strength in older men who engaged in resistance training was highly dependent on neural changes, such as increased frequency of motor neuron discharge and recruitment of motor units. Due to such studies, it was long believed that strength gains from resistance training in older individual’s were primarily due to neural adaptation rather than muscle hypertrophy.

The nervous system responds to resistance training by increasing the activation and recruitment of motor units and by decreasing the co-contraction of antagonistic muscle groups. Recruiting additional motor units as well as increasing the frequency of firing results in greater muscular force production. Some evidence suggests that the central drive from higher neural centres (e.g., motor cortex of brain) changes and that the amounts of neurotransmitters and postsynaptic receptors at the
neuromuscular junction increase. These changes facilitate the activation and recruitment of additional motor units, thereby increasing force production.

In the past, it was believed that neural adaptations are primarily responsible for strength gains only during the initial stage (first 2-8 weeks) of resistance training. At about eight to ten weeks of resistance training, muscle hypertrophy contributes more than neural adaptation to strength gains, but hypertrophy eventually levels off (Sale, 1988). Evidence suggests that muscle hypertrophy is finite and may be limited to no more than twelve months. Given that long-term resistance training (>6 months) continues to increase strength without hypertrophy, experts now believe that a secondary phase of neural adaptation is most likely responsible for strength gains occurring between six and twelve months of training. (Sale, 1988) 49

Resistance training is now a popular activity utilized by both men and women of all ages as an attempt to improve physical condition. However, there is still much controversy concerning the beneficial effects of resistance training and among the four training methods, currently advocated isotonic training is probably the most commonly utilized and prescribed method of training. It has also been the force of the majority of research, but as yet no constant resistance program has been shown to be the most effective for producing optimal improvements. Though many methods prevail to develop strength, the role of progressive resistance training is an undisputed one. Numerous researches have been carried out on the effects of progressive resistance training, but still the bone of contention is about the number of sets, repetitions and duration to get the maximum benefit. Experts differ in their views based on their studies.

Most of the resistance training studies have been carried out in foreign countries using the sophisticated equipments and devices. Hardly few explorations have been made in India, in the area of resistance training and its effect on physical, physiological and biochemical parameters.

While resistance training has long been widely used by bodybuilders, power lifters and competitive athletes to develop strength and muscle size, participation in
weightlifting by individuals of all ages and levels of athletic interest has increased dramatically over the past twenty years. The popularity and widespread appeal of weightlifting exercise for general muscle conditioning, challenge exercise specialists and personal trainers to develop resistance training programs that can meet the diverse needs of trainees.

STATEMENT OF THE PROBLEM

The main purpose of the study was to assess the, “Influence of different resistance training protocols on selected physical, physiological and biochemical variables of college men students.”

OBJECTIVE OF THE STUDY

The primary objective of the present study was to analyze the influence of resistance training on selected physical, physiological and biochemical variables among college male students.

The secondary objective of the study was to find out the differences among the effects of various resistance training protocols on selected physical, physiological and biochemical variables among college male students.

Final objective of the study was to judge the suitable resistance training protocol for the overall (physical, physiological and biochemical) development among college male students.

The research scholar was much interested to study on the area of resistance training and its effect, since only few studies has been explored in India, when compared with foreign countries.
HYPOTHESES
Following were the hypotheses for this study:

1. It was hypothesized that there would be significant improvement on selected physical fitness variables such as speed, explosive power, muscular strength and muscular endurance for all the three experimental groups compared to control group.

2. It was hypothesized that there would be significant difference among the effects of three different resistance training protocols on selected physical fitness components.

3. It was hypothesized that there would be significant improvement in selected physiological variables such as resting pulse rate, $V_{O2}$ max and systolic blood pressure for all the three experimental groups compared to control group.

4. It was hypothesized that there would be significant difference among the effects of three different resistance training protocols on selected physiological variables.

5. It was hypothesized that there would be significant improvement in selected biochemical variables such as triglycerides, LDL, HDL and total cholesterol for all the three experimental groups compared to control group.

6. It was hypothesized that there would be significant difference among the effect of three different resistance training protocols on selected biochemical variables.

DELIMITATIONS

1. Only male students of Pandit Jawaharlal Nehru College of Agriculture & Research Institute, Karaikal having compulsory physical education programme on their curriculum (0+1 course) served as subjects for this work.

2. The age of subjects ranged from twenty to twenty five years.

3. The number of subjects were restricted to sixty (N= 60).

4. The training periods were restricted to sixteen weeks.

5. The 60 subjects were divided randomly into four groups of fifteen each, out of which group I (n=15) underwent resistance training with high intensity and low volume, group II (n=15) underwent resistance training with low intensity and high volume, group III (n=15) underwent resistance training with manipulated intensity and volume and group IV (n=15) served as control group.
6. The following were the variables selected for this study.

**Physical fitness variables**
- Speed
- Explosive power upper body
- Explosive power lower body
- Muscular Endurance
- Muscular Strength

**Physiological variables**
- Resting pulse rate
- VO$_2$ max
- Blood pressure (Systolic)

**Biochemical variables**
- High Density Lipoprotein (HDL)
- Low Density Lipoprotein (LDL)
- Triglycerides (TGL)
- Total Cholesterol

**LIMITATIONS**
1. The physical and physiological fitness level of subjects may vary from person to person.
2. Psychological and sociological aspects of their day to day life interactions to their environment were not kept under control.
3. The food habits, hereditary aspects, life styles of the subjects were not ascertained and this may influence the study.
4. The smoking and drinking habits were not taken into consideration.

**SIGNIFICANCE OF THE STUDY**
Exercises are better tool to improve the physiological and body composition measures and keeps individual healthy. This research work is directed towards finding out the specific resistance training exercise patterns that may have the potential to improve the physical, physiological and biochemical status of individuals.
It may be possible to maintain the data formulated with a reasonable level of accuracy and specificity which could be useful for coaches and training experts to deal with athletes. Besides this, the study would try to focus upon the scope for exercise therapy on weight reduction, on physiological and body composition variables. The research may be instrumental in contributing to human endeavour to find appropriate training schedule for the wholesome physical and physiological improvement.

To brief up the study becomes significant in the following ways

- This study may help to solve the problem of specifying which type of resistance training regimen is more appropriate among various resistance training protocols to improve physical fitness, physiological and biochemical variables.
- The study would propose some useful methods of resistance training exercise which would help in fitness development of sports person.
- This study may be useful in choosing suitable training for an individual whose main purpose is to improve his physical and physiological fitness.
- The resistance training schedule framed for this study would be helpful to exercise therapists, medical experts and the public at large for deciding upon strategies for healthy life.
- This study may add quantum of knowledge to the experts of physical education and sports especially in the areas of exercise physiology and biochemistry.

DEFINITION OF TERMS

Training

“Training has been defined as a programme of exercise designed to improve the skills and increase the energy capacities of an athlete for a particular event”. (Fox, 1984) 

“Training as a medication of general and special exercise which are performed to bring the athlete to his peak condition at the time of competition”. (Dumane, 1971)
According to Harree “Sports training is a pedagogical process, based on scientific principals, aiming at preparing sportsmen for higher performances in sports competition” (Singh, 1995)  

**Load Intensity**

“Intensity of load is the degree of effort being made by the sportsman while doing on exercise. The degree of effort always considered in relation time or repetitions”. (Singh, 1995)  

**Load volume**

“The volume of load is the total amount of work done through and exercise or in a training session. The total amount of work done always considered in relation to distance or number or kilogram or total hours”. (Singh, 1995)  

**Speed**

According to Theiss and Schnabel “Speed is the performance prerequisite to do motor actions under given conditions in minimum of time”. (Singh, 1995)  

“Speed of movement is a prized quality in athletics. Speed of movement shall be defined as the rate at which a person can propel his body or parts of his body through. (Barrow and Megee, 1966)  

**Maximum Strength**

“It is the ability to overcome maximal resistance. It is measured by finding out the maximum resistance which can be overcome or the maximum force which can be applied by the muscles.” (Singh, 1995)  

**Explosive Power**

“It is the capacity of an individual to bring into play maximum muscle contraction at the fastest rate of speed”. (Barrow and Magee, 1966)  

“Explosive power is the ability to release maximum muscular force in the shortest time as in executing a standing broad jump”. (Baumgartner and Jackson, 1987)
**Strength endurance**

“It is the ability of muscle to get over resistance of medium intensity of stimulus for as long time as possible. The best examples are long distance races in track and field, swimming, distance cycling, wrestling, boxing etc. (Singh, 1995)" 

**Resting Pulse Rate**

“The number of beats of a pulse per minute or the number of heart beats per minute”. (William Geddie1964)" 

**Triglycerides**

“The most commonly occurring type of fat found in the diet and body of humans. Triglycerides consist of a glycerol backbone with three fatty acids attached”. (Fink, 2006)" 

**Phospholipids**

“A type of lipid that consists of a glycerol backbone, two fatty acids and a phosphate group. Phospholipids are derived from both plant and animal sources and are both water- and fat soluble.” (Fink, 2006)" 

**Cholesterol**

“A category of lipids that possess carbon rings in their structure rather than carbon chains. Cholesterol is the most commonly known sterol”. (Fink, 2006)"
References


