CHAPTER I
INTRODUCTION

1.1. INTRODUCTION

Physical exercise is an intervention used by many for a multitude of purposes including the attainment and maintenance of health and fitness as well as the enhancement of sports performance. A number of fitness components such as musculoskeletal strength, cardio respiratory endurance, and body composition are differentially affected by the wide array of exercise training programs administered in both the public and athletic sectors. It has been well documented that while strength training improves skeletal muscle force production by increasing muscle cross sectional area (Bell, et al., 2000, Goldberg, et al., 1975, Hakkinen, et al., 2003, Harber, et al., 2004, Kraemer, et al., 1995, Mccarthy, et al., 2002, Nelson, et al., 1990) and glycolytic enzyme concentration (Bell, et al., 2000), endurance exercise enhances the aerobic processes within skeletal muscle by increasing capillary and mitochondrial densities (Crenshaw, et al., 1991) as well as oxidative enzyme concentration (Bell, et al., 2000, Gibala, et al., 2006, Nelson, et al., 1990). While these adaptations are specific to each training mode, they are also divergent in that strength training has been shown to diminish the ratio of mitochondria (Luthi, et al., 1986 and MacDougall, et a., 1979) and capillaries (Tesch, et al., 1984) to muscle cross sectional area and to decrease aerobic enzyme activity (Chilibeck, et al., 2002).

1.2. ENDURANCE TRAINING

Endurance training involves the performance of dynamic submaximal muscular contractions with large muscle groups, and is essentially aerobic (Gergley
2009). However, training at different intensity levels appears to produce different physiological adaptations or primary focus of change (Docherty and Sporer, 2000). Aerobic exercise, which involves prolonged muscular work, increases aerobic capacity through numerous adaptations at the cardiorespiratory and muscular levels (Chromiak and Mulvaney, 1990). Changes in skeletal muscle include increases in mitochondrial content and capillary density, intramuscular myoglobin, and activities of key enzymes of citric acid cycle and mitochondrial electron transport chain with a concomitant increase in mitochondrial protein concentration (Gollnick, et al., 1973; Holloszy and Coyle, 1984; and Tanaka and Swensen, 1998). Increased capillary supply of blood to the skeletal muscle may play a vital role in determining aerobic metabolic function (Hepple, et al., 1997). In addition, increases in the mitochondrial content and respiratory capacity of the trained muscle will result in a slower rate of utilization of muscle glycogen and blood glucose, a greater reliance on fat oxidation, and less lactate production during submaximal exercise (Hawley, 2009). Repeated bouts of endurance exercise may cause increases in slow-twitch fiber area and possibly even elicit a conversion of fast-twitch fibers to slow-twitch fibers (Simoneau, et al., 1985). Chronic adaptations in skeletal muscle are likely to be the result of the cumulative effect of repeated bouts of exercise, with the initial signaling responses leading to such adaptations occurring after each training session (Hawley, 2009). Changes in muscle bioenergetics and enhanced morphological, metabolic substrate and acid-base status will lead to increased maximal aerobic capacity (Gollnick, et al., 1973; Holloszy and Coyle, 1984; and Tanaka and Swensen, 1998). After the adaptation to endurance exercise the same work requires a smaller
percentage of the muscles’ maximum respiratory capacity and therefore results in fewer disturbances in homeostasis (Holloszy and Coyle, 1984).

Doing endurance training ensures better health to the heart as well as improves functioning of the joints and the muscles. It is in order to develop remarkable resistance to fatigue, performing endurance training exercises is the best option. Aerobic endurance, anaerobic endurance, speed endurance and strength endurance are the types of endurance. A sound basis of aerobic endurance is fundamental for all sporting events (Cornelissen and Fagard, 2005).

1.3. ENDURANCE TRAINING ON PHYSIOLOGICAL VARIABLES

It has been shown that aerobic exercise can be an important component of weight loss intervention (Tremblay, et al., 1994), and, therefore, commonly included as part of a comprehensive weight loss management program. However, there is a controversy over whether high intensity exercise or low intensity exercise is more important for stimulating a decrease in the body fat content. The percentage of fat decreases more from low intensity (LI) than high intensity (HI) aerobic exercise (Girandola, 1979). However, other studies have reported no differences on %BF between LI and HI aerobic exercise in overweight sedentary women (Duncan, et al., 1991). Nevertheless, Bryner, et al., (1997), and Tremblay et al., (1994) reported that relative body fat decreases more in young overweight women in the case of HI rather than LI aerobic exercise. Although it is high on the agenda in lipid research, plaque regression ceased to be a research focus of exercise research in recent years. Two decades ago, a series of angiographic long-term follow-up studies documented that regular endurance exercise training can retard the progression of coronary atherosclerosis (Schuler, et al., 1992; and Niebauer, et al., 1992).
An aerobic endurance training in particular leads to numerous health benefits, and there is great evidence for its favorable influence on weight (Donnelly, et al., 2009). And it increases energy expenditure by activation of lipolysis (Poehlman and Horton, 1989). Therefore, aerobic training affects the reduction of weight and body fat (Ballor, et al., 1988).

1.4. ENDURANCE TRAINING ON LIPID PROFILES

Research has found positive training related adaptations on TC, TG, LDL-C and HDL-C (Halverstadt, et al., 2007), or only on LDL-C and TC/HDL-C, without changes on TC, HDL-C and TG (Kelley, Kelley and Tran., 2004). However, the variety of characteristics (frequency, intensity, time, and type) of exercise used in previous studies may partly explain inconsistent findings of different modes of aerobic exercise causing unchanged TC, HDL-C or LDLC (Sillanpaa., et al., 2009). Additionally, some studies focusing on the effects of the gender in the lipid profile have found significant differences, with women having higher HDL-C, decreased LDL-C, and decreased TG comparing with men (Garelnabi, et al., 2010). Regular endurance exercise is a widely recognized modality to raise plasma HDL cholesterol levels, (Després, et al., 1991; Durstine and Haskell., 1994; and Hardman, 1999) which is one of the metabolic adaptations contributing to the reduced risk of coronary heart disease (CHD) observed among physically active and fit individuals.

1.5. STRENGTH TRAINING

Resistance training is known to improve muscular strength and power, cause hypertrophy and can even improve muscular endurance (Kraemer and Ratamess, 2004). These various outcomes of training are brought about as a result
of manipulating certain variables including the number of sets performed, the intensity of each set and the entire workout, as well as the rest periods between sets and exercises (Campos, et al., 2002). Muscles are constantly involved in exerting the forces required to perform everyday regular activities (Macaluso, et al., 2003) and therefore certain levels of strength and power are required for functional movements. However, within certain sports (eg. weightlifting and sprinting), strength and power can often play a large part in determining success (Tan, 1999).

When resistance training is performed by athletes it is generally categorised as either sport-specific or non-specific. These terms describe how closely the training movements match the actual muscle actions performed during the sporting event. Thus, for optimal improvement, recruitment patterns performed during resistance training should match the recruitment patterns performed during the sporting event as closely as possible. When considering whether to include resistance training into the training program of an endurance athlete, there are many factors that one must consider regarding the principle of specificity. As discussed above, there are different types of resistance training (strength, power, and hypertrophy) and it is vital that coaches incorporate only valuable training interventions into their athletes’ training programs. Furthermore, there are both sport-specific and non-specific types of resistance exercise (Pearson, et al., 2000). The general types of resistance exercise listed above are usually performed using free-weights or machine-weights in a non-specific manner that may engage muscles that might not primarily be recruited during an athletes’ sport. Conversely, sport-specific training targets the muscles used during performance and replicates those specific motor patterns against resistance.
Early strength gains achieved during a strength training program have been attributed to increases in neuromuscular function rather than initial muscular hypertrophy (Hickson, et al., 1988; and Tan, 1999). The neuromuscular status of the muscle is altered through resistance training by enabling either a greater muscle fibre recruitment (i.e. more active motor units) or by increasing the firing frequency of the motor units (i.e. creating larger forces by increasing the number of cross-bridge connections) (Docherty and Sporer, 2000). It should be expected that these same neuromuscular adaptations will occur when an untrained individual commences a program of concurrent resistance and endurance training. Trained athletes are less likely to incur noticeable changes described above since these are common only in early phases of training and athletes already have a well established base of strength. It is perhaps more surprising though that to date studies with well-trained cyclists have not reported whether neuromuscular changes occurred following resistance training (Bastiaans, et al., 2001; and Bishop, et al., 1999). Despite being well-trained, cyclists typically do not include any form of traditional strength training into their training routines. It has been suggested by Hawley and Stepto (2001) that the immense volume of endurance training performed by well-trained cyclists causes the neuromuscular changes to already have occurred.

The strength as a motor skill is usually divided on maximum, explosive, repetitive, and static. Some of the activities have specific aims, i.e. the final aim determines the development of a specific strength, and based on that the entire training process is planned (Hakkinen, et al., 2003). The first thought that comes to mind when the strength training is mentioned is a muscular hypertrophy, the examinees' previous activities, and their initial state which will significantly
influence the training results (Ahtiainen, et al, 2003; and Hakkinen, et al., 1989). The strength training is a confirmed method for the increase of fat-free mass (Willis, et al., 2012 and Treuth, et al., 1994). It is also a good choice for the prevention of the increase in the total body fat percentage (Schmitz, et al., 2007), and an efficient method for the decrease of subcutaneous adipose tissue (Slentz, et al., 2011). For that precise reason, it is very popular method of intervention in the case of obese people. With strength training the fat-free mass is increased and, at the same time, the percentage of adipose tissue is reduced (McGuigan, et al., 2009 and Van, et al., 1997). There is also an increase in daily energy requirements and resting energy expenditure (Campbell, et al., 1994), therefore the intensity of the training should be kept in mind (Paoli, et al., 2012). The strength training is recommended for people suffering from type 2 diabetes, also for the prevention of the cardiovascular diseases (Lebr, et al., 2011 and Zacker, 2005), and it lowers the tumor mortality risk among men (Ruiz, et al., 2009). It is the only training method which can slow down sarcopenia (Zacker, 2005), and it has a great role in osteoporosis prevention (Hurley and Roth, 2000).

Resistance training in contrast to endurance training contains the low repetition performance with near maximal muscular contractions and has been shown to increase maximal contractile force (Gergley, 2009). Improvements in muscular strength occur as a result of an increase in muscle cross-sectional area (CSA) and the ability to effectively activate motor units. The increase in CSA of muscle is considered to occur as a result of protein synthesis, which produces a greater amount number of contractile units. Enhanced motor unit activation results from a greater number of fibers being recruited, increasing firing frequency,
decreased co-contraction of agonists, better motor unit synchronization and inhibition reflexive mechanisms. (Docherty and Sporer, 2000). Strength training is primarily anaerobic and results in increased muscle glycolytic enzyme activity, and intramuscular ATP/phosphocreatine stores, along with hypertrophy of muscle fibers a possible reduction of muscle mitochondrial and capillary density may appear (Tanaka and Swensen, 1998; and Costill et al., 1979). The magnitude of hypertrophy or strength improvements depends on the volume and intensity of the training stimulus (Docherty and Sporer, 2000). Only the muscles which are exercised will experience adaptive changes, whereas non-exercised muscles will experience little or no training effect (Bottinelli, et al., 1999). Low-resistance exercise such as cycling, running, and swimming, is mainly accomplished through an increase in maximal oxygen uptake and an increased ability of skeletal muscle to generate energy via oxidative metabolism without improvements in muscle strength (Nader, 2006).

1.6. STRENGTH TRAINING ON PHYSIOLOGICAL VARIABLES

Weight training is a critical component to the success and become stronger, increasing muscular endurance; it is help to perform more efficiently and is better able to avoid injury. Furthermore, there are a number of other physiological adaptations to weight training. The strength of tendons and ligaments are increased. Bone density increases, making the bone stronger and more resistant to fractures. And maximal heart rate is improved, thus increasing metabolism. The strength training is a confirmed method for the increase of fat free mass (Willis, et al., 2012). It is also a good choice for the prevention of the increase in the total body fat percentage (Schmitz, et al., 2007). For that precise reason, it is very popular method
of intervention in the case of obese people. With strength training the fat-free mass is increased and, at the same time, the percentage of adipose tissue is reduced (McGuigan, et al., 2009).

Some more studies shows that the relationship with strength training and physiological variables. Three months of supervised progressive resistance training induced improvements in maximal voluntary thigh muscle strength and whole body FFM in frail, community-dwelling elderly women and men. This supervised exercise program may not be sufficient to reduce whole-body or intra-abdominal fat area in this population (Binder, et al., 2005). The strength-training had significant increases BMR and muscular strength (Dolezal and Potteiger, 1998). High-intensity progressive resistance training (PRT) improves adiposity and metabolic risk in adults, but has not been investigated in children (Girls and boys) within a randomized controlled trial (RCT). Concealed randomization stratified by age and gender. High-intensity PRT significantly improved waist circumference, fat mass, percent body fat, body mass index (Benson, Torode and Singh, 2008).

1.7. STRENGTH TRAINING ON LIPID PROFILES

It is well established that physical inactivity is related to decrease high density lipoprotein cholesterol (HDL-c) and exceeded triglycerides (TG) concentrations, which contribute, at least partially, to increased atherosclerotic disease(s) risk (Leaf, 2003). On the other hand, chronic exercise training has favorable effects on lipid profile (Durstine, et al., 2003; Belmonte, et al., 2004; Lira, et al., 2008). In this context, increased exercise practice, mainly continuous aerobic exercise, has been considered one of the best non-pharmacological strategies in preventing and treating cardiovascular diseases (Epstein, 1995).
Executing resistance training sessions by 16 weeks (80% of 10-RM, three times a week) did not show changes in lipid profile, although presented improved muscle strength of post menopausal women. On the other hand, premenopausal women trained during 14 weeks (85% of 1-RM, three times a week) showed a 9% decrease in total cholesterol, 14% decrease in LDL-cholesterol, and 14.3% in the ratio total cholesterol/HDL-c (Elliott, Sale and Cable, 2002). In another study performed with untrained males comparing two different protocols (low vs. high-repetition; 5-RM and 15-RM, respectively) by 10 weeks (three times a week) showed no difference in lipoprotein profiles (Kokkinos, et al., 1988). Finally, a meta-analysis of randomized controlled trial showed that chronic resistance training decreased total cholesterol, LDL-cholesterol, TG, and increased HDL-c (Kelley and Kelley, 2009). When the main issue is acute exercise, little is known about the acute resistance training upon blood lipid profile in healthy people. Thus, few information exist about the effects of different resistance exercise intensities on lipid profile. The effective exercise training in lipid profile is dependent of exercise intensity, duration and frequency of each session associated with the length of the exercise training period (Park and Ransone, 2003). In comparison with endurance training, it has been reported that resistance exercise will properly reduce LDL-C concentration and increase HDL-C concentration (Joseph, et al., 1999).

The progressive resistance training (PRT) on lipids and lipoproteins in adults Primary outcomes included total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), ratio of total cholesterol to high-density lipoprotein cholesterol (TC/HDL-C), non-high-density lipoprotein cholesterol (non-HDL-C), low-density lipoprotein cholesterol (LDL-C), and triglycerides (TG). A random-effects model
was used for analysis with data reported that the TC, HDL-C, TC/HDL-C, non-
HDL-C, LDL-C, and TG. Progressive resistance training reduces TC, TC/HDL-C, 
non-HDL-C, LDL-C and TG in adults (Kelley and Kelley, 2009). The acute 
resistance exercise may induce changes in lipid profile in a specific-intensity 
manner. Overall, low and moderate exercise intensities appear to be promoting more 
benefits on lipid profile than high intensity (Lira, et al., 2008). In comparison with 
endurance training, it has been reported that resistance exercise will properly reduce 
LDL-C concentration and increase HDL-C concentration (Goldberg, et al., 1984; 
and Joseph, et al., 1999). There are also contradictory results in this case 
(Kokkinos, et al., 1991; and LeMura, et al., 2000).

1.8. CONCURRENT TRAINING

It is these divergent adaptations coupled with the need to improve both 
strength and endurance that has led researchers to investigate the effect that one 
mode of training has on the other during a concurrent strength and endurance 
training program. If an interaction is to occur between the two modes, the literature 
suggests it is the adaptations to endurance exercise that inhibit those to strength 
exercise, and not the opposite (Bell, et al., 2000, 1997; Dolezal and Potteiger, 

In addition to the aforementioned adaptations, strength and endurance 
exercise produce changes in body composition by two very different mechanisms. It 
is known that improvements in body composition (i.e., a reduction in percentage of 
fat mass) are the result of increases in energy expenditure in conjunction with either 
a constant or reduced caloric consumption. Strength exercise accomplishes this 
increase in expenditure on a long-term basis by increasing fat free mass, which has
been shown to be consistent with increases in resting metabolic rate (Dolezal and Potteiger, 1998; Lemmer, et al., 2001; and Pratley, et al., 1994). Endurance training, on the other hand, impacts body composition on an acute basis by increasing total caloric expenditure in direct proportion to the caloric cost of the exercise (Bloomer, 2005). When combined, these differential effects of strength and endurance exercise are additive in that concurrent training has been shown to elicit increases in fat-free mass (Dolezal and Potteiger, 1998; and Glowacki, et al., 2004) as well as decreases in body fat percentage (Dolezal and Potteiger, 1998; Glowacki, et al., 2004; Hakkinen, et al., 2003; and Hennessy and Watson, 1994); however, the magnitude of the increase in fat-free mass is often attenuated in accordance with any attenuations in strength (Bell, et al., 2000, and Kraemer, et al., 1995). Under certain conditions, the caloric cost of endurance exercise becomes such that a caloric deficit is maintained for a prolonged period of time, and a reduction in resting metabolic rate can result from the degradation of fat-free mass caused by the excess energy utilization (Bryner, et al., 1999; and Dolezal and Potteiger, 1998). The exact mechanisms for muscle tissue growth and degradation have not been fully elucidated; however, a number of investigations have revealed that the anabolic hormone, testosterone, and the catabolic hormone, cortisol, play a prominent role in these changes to skeletal muscle (Fry, et al., 2000; Hakkinen, et al., 1993&1985; and Kraemer, 1990& 1998a, 1998b). The ratio of testosterone to cortisol has been shown to be an effective correlate of both strength gains with training (Fry, et al., 2000) and endurance training volume (Filaire, et al., 2001; and Maso, et al., 1990); however, the response of these hormones to a concurrent training program is somewhat unclear due to the limited research in this area. The
adaptations elicited by a training program are specific to the training mode, intensity, duration, and frequency, all of which are included in the determination of the total training volume. The fact that a high training volume has been linked to increases in cortisol (O’Conner, et al., 1989) and decreases in the ratio of salivary testosterone to cortisol (Filaire, et al., 2001; and Maso, et al., 1990) has led to the hypothesis that the higher training volume imposed with concurrent training, as compared to that imposed with its respective strength and endurance components, contributes to the existence of interference between strength and endurance adaptations. The concurrent training stimulus can also be changed by altering the rest interval between the strength and endurance exercise sessions. Sale, et al., (1990) provided evidence that maximizing the duration of rest between the strength and endurance exercise sessions optimized the resulting gains in strength with concurrent training when compared to performing the strength and endurance components in immediate succession. Since the training implanted in that study was only specific to the lower-body musculature, it is unknown if a greater total training volume, such as that elicited by a total-body concurrent training program, would elicit the same effect. To date, no study has been conducted to determine whether maximizing the duration of rest between the strength and endurance exercise sessions in a total-body concurrent strength and endurance training program prevents attenuation in strength development while maintaining favorable changes in body composition and resting hormonal concentrations.

From the perspective of promoting health, improvements in both strength and cardiorespiratory fitness are important and concurrent training seems to be the best strategy to enhance those variables (Cadore, et al., 2010). Many of the
combined strength and endurance training studies have investigated simultaneous strength and endurance training to assess whether it produces complementary or antagonistic adaptations in physical fitness (Cadore, et al., 2011). Combined strength and endurance training studies have proposed divergent results, showing that it can lead to similar cardiovascular or musculoskeletal adaptations compared with either training regime alone (McCarthy, et al., 2002; and Izquierdo, et al., 2005), increase endurance performance (Storen, et al., 2008) or a diminished range of musculoskeletal and/or cardiovascular adaptation (Nelson, et al., 1990; Izquierdo et al., 2005; and Hickson 1980). Reasonable physiologic and metabolic evidence exists to support interference as aerobic endurance and resistance training represent the opposite ends of adaptation continuum (Glowacki, et al., 2004; and Coffey and Hawley, 2007).

The results of several studies have shown that 10–12 weeks of concurrent training, with a weekly frequency between 4 and 11 sessions, with intensities ranging from 60% to 100% of VO2max for endurance and from 40% to 100% of 1RM for resistance training, resulted in increases ranging from 6% to 23% in VO2max and 22% to 38% of maximum strength (Kraemer et al., 1995; and Hickson, 1980). Whereas, in the majority of studies the increases in maximum strength were higher in the group that performed only strength training compared with the concurrent training group referring to “interference effect” reported already in 1980 by Hickson. Nevertheless, the majority of concurrent research supports the contention that concurrent training does not alter the ability to positively adapt to endurance training. (Garcia-Pallares and Izquierdo, 2011).
Prior investigations have not systematically examined alterations in independent variables, for example the intensity of training or the sequence and scheduling of concurrent training sessions, it remains unclear as to the extent that variations in the independent variables impact upon the level of strength and endurance response and adaptation. Collins and Snow (1993), in one of the few studies that manipulated the sequence of training by comparing endurance/strength to strength/endurance within the same session over a 7 week period, reported that there was no significant difference between the two sequences as assessed by VO2 max, one-repetition maximum (1 RM) bench press, arm-curl and leg-press strength.

Whilst this suggests that the development of strength and endurance may be independent of the sequence of training, further research is required of the various combinations of training sequences and schedules as well as the other independent training variables, to determine the extent to which training protocols, sequences or schedules influence concurrent training responses and adaptations.

In addition, the majority of prior concurrent training studies have focused on the completion of weeks of training and the subsequent level of adaptation over the course of a combined strength and endurance training regime. The acute strength or endurance responses following a concurrent training session have not been examined. To date most studies that have examined the acute responses to multiple strength training sessions on the same day (Häkkinen, 1992) or following some form of endurance type exercise (Bentley, Zhou and Davie, 1998; and Sahlin and Seger, 1995) have done so from the perspective of maximal voluntary force generating capacity. To date there have been no investigations that have examined the acute physiological effects of prior strength training on
endurance performance. However, evidence from previous studies that have completed two strength (Häkkinen, 1992) or endurance training sessions (Ronsen, Haug, Pedersen and Bahr, 2001) in the one day or other methods of physical training other than resistance training over separate days (Gleeson, et al., 1995), suggest that subsequent activities undertaken using the same muscle groups as those used in a prior activity, maybe adversely affected because of residual fatigue (Häkkinen, 1992) or a higher relative exercise stress (Gleeson, et al., 1995; and Ronsen et al., 2001).

A number of training modalities and protocols have been used in concurrent training studies (Craig, et al., 1991; Dudley and Djamil, 1985; Hortobágyi, Katch and Lachance, 1991; and Sale et al., 1990b). However, there have been no investigations that have examined the impact of using a within-sport strength training mode during a concurrent training program. Whilst the effects of concurrent training, in the form of “in-water” strength and endurance training on swimming endurance performance are unknown (Tanaka and Swensen, 1998), data exists that indicates that swim strength training (in-water) can improve a swimmer’s velocity over distances up to 200 metres (Toussaint & Vervoorn, 1990) as well as stroke force and distance per stroke (Tanaka, Costill, Thomas, Fink, & Widrick, 1993; Toussaint & Vervoorn, 1990). This data suggests that the modality of strength training may play a greater role in improving the compatibility of strength and endurance training than using traditional strength training methods. However, further research is required for swimming and other types of endurance sports such as cycling and running before the extent of compatibility of within-sport strength and endurance training can be known.
1.9. CONCURRENT TRAINING ON PHYSIOLOGICAL VARIABLES

Concurrently training has numerous physiology adoptions to the body, including neuromuscular, skeletal-muscular, cardio respiratory and the endocrine system. Combined aerobic and resistance training is the best program to treat obesity (Hill, et al., 1987). Moreover, doing a combination of strength and endurance training is more beneficial for weight loss and change body composition (Hendrickson, et al., 2010). The obtained results indicated that concurrent training can significantly increase basal metabolism and decrease body fat relative LDL to the obtained amounts in the before-training period (Dolezal and Potteiger, 1998). In addition, the significant decrease of subcutaneous fat, body fat percentage and waist-to-hip ratio after performing eight weeks of combined strength and endurance training (Maiorana, et al., 2002; and Akbarpour, Assarzadeh and Sadeghian, 2011). Also a lack of change in body composition after performing 10 and 16 weeks of combined strength and endurance training in healthy women (Pochlman, et al., 2000, LeMura, et al., 2000). The concurrent training for adolescents showed statistically significant improvement in body composition, with a decrease of total body fat percentage, total fat mass, trunk fat, and an increase in the lean body mass (Antunes, et al., 2013).

1.10. CONCURRENT TRAINING ON LIPID PROFILES

The effects of various modes of training (endurance, resistance and combination exercise) on changes in blood lipids after 16 weeks of training and 6 weeks of detraining in young untrained women. It was reported that 16 weeks of combination training did not result in any significant changes in blood lipids (LeMura, et al., 2000). Azarbayjani et al., (2012) reported that resistance exercise
has more positive effects on changes in lipid profile than aerobic and concurrent exercises.

The result showed that both groups Strength & Endurance (SE) and Endurance & Strength (ES) significantly improved lipid profile (significantly reduces in TC, TG, LDL-C, VLDL-C and significantly increased HDL-C) and body composition (significantly decreased in body fat, body weight and increased body fat free mass but no significant) when compared to control group. Also no significant difference found between SE and ES groups in the lipid profile and body composition. It can be concluded that both SE and ES protocols nearly identical effects in positive transformation of lipid profile and body composition (Ali-Mohamadi, et al., 2014).

Based on the above facts the aim of this study was designed to findout the effect of endurance, strength and concurrent training on physiological variables and lipid profiles among college women players.

**1.11. OBJECTIVES**

The following are the specific objectives of this study.

1. To find out the effect of endurance, strength and concurrent training on selected physiological variables among college women players.
2. To find out the effect of endurance, strength and concurrent training on selected lipid profiles among college women players.
3. To find out the suitable training procedure to improve the selected criterion variables among college women players.
1.12. STATEMENT OF THE PROBLEM

The purpose of the study was to find out the effect of endurance, strength and concurrent training on selected physiological variables and lipid profile of college women players.

1.13. HYPOTHESES

It was hypothesized that

1. There would be a significant improvement on selected physiological variables due to the effect of endurance, strength and concurrent training among college women players.

2. There would be a significant improvement on selected lipid profiles due to the effect of endurance, strength and concurrent training among college women players.

3. There would be a significant improvement difference among the endurance, strength and concurrent training on selected criterion variables among college women players.

1.14. DELIMITATIONS

The study was delimited to the following factors.

1. To achieve the purpose of the study, 60 college women players who represented inter-collegiate and inter university level competitions irrespective of sports and games were selected randomly as subjects from Govindammal Aditanar College for Women, Tiruchendur. The age of the subjects ranged between 18 and 25 years.
2. The selected subjects were divided into three experimental groups Group I - ETG (Endurance Training Group), Group II – STG (Strength Training Group), Group III - CTG (Concurrent Training (combination of Endurance and Strength Training) Group), and Group IV – CG (Control Group) with fifteen subjects (n=15) each.

3. The following dependent variables were selected for this study: Physiological variables namely Fat free mass, Body Fat, and BMR and Lipid Profiles namely HDL-C, LDL-C, and Total Cholesterol.

4. The duration of the training period was restricted to eight weeks and the number of sessions per week was confined to three.

5. The data were collected prior to and also immediately after the training period.

6. The level of significance is fixed at 0.05 level, which was considered to be appropriate.

1.15. LIMITATIONS
1. Subject’s previous training and performance were not considered.

2. The food habits, other regular habits and life style would not be controlled.

3. While conducting this study the external factors like air resistance atmospheric conditions, physical condition of the subjects, etc., would not be taken into considered.

1.16. DEFINITION AND EXPLANATION OF THE TERMS

1.16.1. College Women Players

Those who are studying in either under graduation or Post graduation degree as well as they are participated in inter-collegiate or inter-university games and sports competitions.
1.16.2. Training

Training may be defined as, “systematic process of repetitive progressive exercise or work involving the learning process and acclimatization (Arnhein, 1985).

1.16.3. Endurance Training

Physical training for athletic events requiring prolonged effort, such as running a marathon, swimming a long distance, or climbing mountains [http://medical-dictionary.thefreedictionary.com/endurance+training].

In the current study, the endurance training during the supervised sessions was the continuous run, jump rope and aerobic exercises. During the warming up sessions, before the endurance training exercises like stretching, jogging, striding, parallel squats, arms rotation and jump and toe touch were done.

1.16.4. Strength Training

The term strength training the use of (barbells, dumbbells, machines, weighted vests, bars, elastic tubing and so on) such 27 equipments for the express purpose of improving athletic performance. (Baechle and Groves, 1992).

In the current study, the strength training during the supervised sessions was the bench press, heal rise, half squat, military press - front and back exercises. During the warming up sessions, before the strength training exercises like stretching, jogging, striding, parallel squats, arms rotation and jump and toe touch were done.
1.16.5. 1 RM

1RM = One Repetition Maximum

The maximum amount of weight that a person can lift once; 100% of one’s lifting capacity.

1.16.6. Concurrent Training

Concurrent training is one method that many coaches employ as it consists of training multiple qualities at equal amounts of focus within the same training phase and often within the same workout.

In the current study, the combined training during the supervised sessions, endurance training followed by strength training were given within the same training session.

1.16.7. Body Composition

Body composition refers to the relative amount of muscle, fat, bone and other vital parts of the body. A person’s total body weight may not change over time. But the bathroom scale does not assess how much of that body weight is fat and how much is lean mass, body composition is important to consider for health and managing. (Johnson and Nelson, 1988).

1.16.8. Fat Free Mass

Fat-free mass is one of two human body components. Fat-free mass (FFM) includes internal organs, bone, muscle, water and connective tissue. (Jennifer R. Scott, 2016).
1.16.9. Body Fat

Body fat is the most variable tissues in the body and it is distributed throughout in the abdominal cavity. (Earle, 1982).

1.16.10. Basal Metabolic Rate (BMR)

It is a measure of the minimal amount of energy (kcal) needed to maintain basic and essential physiological (such as heart beat, breathing and cell metabolic activities) process in a relaxed, awake and reclined state. (Heyward, 2002)

1.16.11. High-Density Lipoprotein

HDL, a type of protein molecule carried in the blood that removes cholesterol from tissues and appears to protect against coronary heart disease. Reduces the development of atheroma and atherosclerosis. HDL was estimated by phophotungstate method and is expressed as mg/dl. (McArdle and Katch, 1991)

1.16.12. Low-Density Lipoprotein

Low Density Lipoprotein Cholesterol is the major cholesterol carrying lipoprotein. Elevated LDL levels herald a strong predisposition to coronary heart disease, stroke and peripheral vascular disease. LDL was calculated using Priedwalad’s equation and expressed as mg/dl. (McArdle and Katch, 1991)

1.16.13. Total Cholesterol

Cholesterol is the fatty substance formed in the blood. Cholesterol is a white fatty alcohol of steroid group, found in body tissue, blood and bile, assists in synthesis of vitamin D and various hormones. Excessive deposits of cholesterol inside arteries are associated with arteriosclerons and coronary heart disease. TC was
estimated using erymatic calorismetric method and expressed as mg/dl. (Mc Ardle and Katch, 1991).