Chapter II

REVIEW OF RELATED LITERATURE

For any specific research project to occupy a place in the development of a discipline, the researcher must be thoroughly familiar with both previous theory and research. To assure this familiarity, every research project in the behavioural sciences has as one of its early stage, a review of the theoretical and research literature.

The literature related to any problem helps the scholar to discover what is already known, which would enable the investigator to have a deep insight, clear perspective and a better understanding of the chosen problem and various factors connected with the study. So a number of books, journals and websites were referred. In the following pages, an attempt has been made to present briefly a few of the important researches and studies conducted abroad and in India as they have significant bearing on the present study.

The literature in any field forms the foundation upon which all future work will be built. If we fail to build upon the foundation of knowledge provided by the review of literature, the researcher might miss some work already done on the same topic.
The following review of literature addresses the effect of varied intensities of endurance training on physical and physiological parameters. Terms relevant to the study in this thesis are operationally defined.

The literature in any field forms the foundation upon which all future work will be built. If we fail to build upon the foundation of knowledge provided by the review of literature, the researcher might miss some works already done on the same topic. The reviews of the literature have been classified under the following headings.

1. Studies on Varied intensities of interval training on physical variables.

2. Studies on varied intensities of Interval training on physiological variables.

3. Summary of Literature

**Studies on Varied Intensities of Interval Training on Physical variables**

**Hickson (1980)** determined how individuals adapt to a combination of strength and endurance training as compared to the adaptations produced by either strength or endurance training separately. There were three exercise groups: a strength
group (S) that exercised 30--40 min. day-1, 5 days. week-1, and endurance group (E) that exercised 40 min. day-1, 6 days. week-1; and an S and E group that performed the same daily exercise regimens as the S and E groups. These findings demonstrate that simultaneously training for S and E will result in a reduced capacity to develop strength, but will not affect the magnitude of increase in VO2max.

**Ready, Eynon & Cunningham (1981)** evaluated the effect of interval training and detraining on anaerobic fitness in women. Seventeen female volunteers (x age = 23.9 yr) participated in a 6 week investigation of the effect of high intensity interval training on anaerobic fitness. The subjects were randomly assigned to a treatment (exercise n = 9) or a control (no exercise n = 8) group. The training program consisted of 10 one minute work periods on the bicycle ergometer separated by one minute rest periods. This was done 3 days per week. The control group did not change significantly on any of the selected parameters. After 2 weeks of detraining oxygen debt decreased significantly to its pretraining value. The retention of increases in post exercise peak blood lactate and time of bicycle ride to exhaustion was 40% and 38% respectively. Twenty-four
% of the increase in VO2 max induced by the training regime was retained.

**Lortie et al (1984)** investigated the individual differences and the specificity in the response of maximal aerobic power (MAP) and capacity (MAC) to a 20-week aerobic training program. Twenty-four subjects (25 +/- 4 years), ascertained as sedentary, including 13 women and 11 men, participated in this study. MAP was determined with a progressive maximal ergocycle test, while MAC was computed as the total work output accomplished during a 90-min maximal ergocycle test. These results indicate that there is a sex difference in the trainability of aerobic capacity, but not of maximal aerobic power, under the same 20-week aerobic training program. Finally, there is a high level of specificity in the response to training of the power and of the capacity of the aerobic energy metabolism.

**Hickson, Foster, Pollock, Galassi & Rich (1985)** discussed the reduced training intensities and loss of aerobic power, endurance. Twelve subjects participated in an exercise program of cycling and running 40 min/day, 6 days/wk. After 10 wk, they continued to train with either a one-third or two-thirds reduction in work rates for an additional 15 wk. Frequency and duration for the additional training remained the
same as during the 10 wk of training. The average increases in maximum O2 uptake (VO2 max) were between 11 and 20% when measured during cycling and treadmill running after 10 wk of training. VO2 max was not maintained at the 6-day/wk training levels with a one-third reduction in training intensity but was still higher than pretraining levels. These results demonstrate that training intensity is an essential requirement for maintaining the increased aerobic power and cardiac enlargement with reduced training.

**Neufer, Costill, Fielding, Flynn & Kirwan (1987)** determined the effect of reduced training on muscular strength and endurance. Following 5 months of competitive training, three groups of eight male swimmers performed 4 wk of either reduced training (3,000 yard.session-1) or inactivity. Two groups reduced their training to either 3 sessions.wk-1 (RT3) or 1 session.wk-1 (RT1), whereas the third group (IA) did no training. These results suggest that aerobic capacity is maintained over 4 wk of moderately reduced training (3 sessions.wk-1) in well-trained swimmers. Muscular strength was not diminished over 4 wk of reduced training or inactivity, but the ability to generate power during swimming was significantly reduced in all groups.
Bell, Petersen, Quinney & Wenger (1988) compared two sequences of endurance (E) and high-velocity resistance (HVR) training, sixteen male oarsmen were separated into Group ES which trained endurance prior to strength and Group SE which trained strength prior to endurance. The endurance program consisted of up to 60 min a session, five days a week for five weeks. HVR exercise was conducted on 12 stations of variable resistance hydraulic equipment, four sessions per week for five weeks. These results show that organizing strength and endurance training into sequential programs can influence the physiological adaptation to training.

Rathnow & Mangum (1990) compared the effects of a 10-week single mode (SM) training program (walk/jog) versus a multimode (MM) training program (walk/jog, cycle, arm crank) on peak aerobic power (VO2 peak) during three ergometry modes. Twenty Ss were stratified initially according to gender and then randomly assigned to either of the treatment groups. Seven additional Ss served as controls. Peak VO2 was determined during treadmill running, cycle ergometry and arm crank ergometry prior to and after ten weeks of training. These data support the concept that a conditioning program can become sufficiently variable so that expected increases in aerobic
power are not produced, despite the fact that isoenergetic training is undertaken.

**Tabata, Atomi, Kanehisa & Miyashita (1990)** determined the effects of high-intensity endurance training on isokinetic muscle power. Six male students majoring in physical-education participated in high intensity endurance training on a cycle ergometer at 90% of maximal oxygen uptake (VO2max) for 7 weeks. The duration of the daily exercise session was set so that the energy expenditure equalled 42 kJ.kg-1 of lean body mass. Peak knee extension power was measured at six different speeds with an isokinetic dynamometer. It was concluded that, the percentage improvement was dependent on the initial muscle peak power of each subject and the training stimulus (intensity of cycle ergometer exercise).

**Jenkins & Quigley (1992)** determined whether critical power (CP) assesses the ability to perform continuous aerobic exercise and to determine whether training-induced changes in aerobic endurance are reflected by changes in the slope, but not the y-intercept of the CP function. Twelve healthy, active, but untrained male students undertook 8 wk of cycle ergometer endurance training (30-40 min a day, three times a week) at an intensity corresponding to their CP. It was concluded that the
critical power was significantly enhanced after the 8 weeks of endurance training.

**Mayhew et al (1995)** determined the accuracy of predicting maximal bench press (BP) strength (1-RM) from relative endurance performance in various groups of men. The subjects included untrained students (n = 35), resistance trained students (n = 28), college wrestlers (n = 21), soccer players (n = 22), football players (n = 51), high school students (n = 35), and resistance-trained middle-aged men (n = 24). Each subject performed a 1-RM test according to the same standard procedure. In conclusion, while caution should be used when employing relative muscular endurance performance to estimate 1-RM strength in the bench press, the average of two equations may reduce the error.

**Duey et al (1998)** examined the effects of a six-week endurance exercise training program on aerobic fitness (VO2peak) in African-American females. Twenty-five women (16 treatment, 9 controls, mean age 23.1+/-3.9) participated in the study. The six-week exercise training protocol consisted of exercising three times a week on a cycle ergometer between 60-70% VO2peak for 20 minutes. These results document the fact that significant increases in aerobic fitness are possible with a
moderate exercise training regime in an African-American female population.

**Leveritt, Abernethy, Barry & Logan (1999)** proposed that repeated acute reductions in the quality of strength training sessions then lead to a reduction in strength development over time. Peripheral fatigue factors such as muscle damage and glycogen depletion have been implicated as possible fatigue mechanisms associated with the acute hypothesis. Further systematic research is necessary to quantify the inhibitory effects of concurrent training on strength development and to identify different training approaches that may overcome any negative effects of concurrent training.

**Leveritt, MacLaughlin & Abernethy (2000)** determined the effects of a single bout of endurance exercise on subsequent strength performance. Eight males with a long history of resistance training performed isokinetic, isometric and isotonic leg extension strength tests 8 and 32 h after 50 min of cycle ergometry at 70-110% of critical power. The participants also completed a control condition in which no cycling was performed. Plasma lactate and ammonia were measured before and immediately after each strength test. Our results suggest
that leg extension strength was not compromised by an earlier bout of endurance cycling.

**Kraemer et al (2001)** evaluated the effects of resistance training programs on strength, power, and military occupational task performances in women were examined. Untrained women aged (mean +/- SD) 23 +/- 4 yr were matched and randomly placed in total- (TP, N = 17 and TH, N = 18) or upper-body resistance training (UP, N = 18 and UH, N = 15), field (FLD, N = 14), or aerobic training groups (AER, N = 11). Two periodized resistance training programs (with supplemental aerobic training) emphasized explosive exercise movements using 3- to 8-RM training loads (TP, UP), whereas the other two emphasized slower exercise movements using 8- to 12-RM loads (TH, UH). In conclusion, gender differences in physical performance measures were reduced after resistance training in women, which underscores the importance of such training for physically demanding occupations.

**Palmer & Sleivert (2001)** determined whether a low-volume high-intensity resistance training session influenced running economy during a subsequent aerobic treadmill run. Nine well trained distance runners with resistance training experience performed treadmill running at two different speeds
(0.56 m x sec(-1) and 0.20 m x sec(-1) below speed corresponding to lactate equilibrium) either rested or 1, 8 or 24 hours after a 50-minute whole body resistance training session. Running economy was assessed using open circuit spirometry while heart rate was recorded telemetrically. In conclusion, the mechanism responsible for increased oxygen consumption following resistance training may be related to impairment of the force generating capacity of skeletal muscle, as there was a significant decrement in the contractile properties of the quadriceps femoris following resistance training.

**(Smith, Fry, Weiss, Li & Kinzey (2001))** determined the effect of high intensity exercise on sprint. Nine men (25.11 +/- 1.16 years) performed 3 different test sessions. In the control session, subjects performed a 10-second sprint cycle test and 1 repetition maximum (1RM) in the back squat. The authors conclude that this particular squat protocol could have a potential carry-over effect into improvements in 100-m sprint times when performing the squats 5-minutes prior to performance.

**(Lagally, Robertson, Gallagher, Gearhart & Goss (2002))** examined perceived exertion was measured at 30% and 90% of the one-repetition maximum (1-RM), while holding work
constant between intensities. Ratings for the active muscles and for the overall body were examined during both intensities. 10 male volunteers underwent a one-repetition maximum procedure for each of the following exercises: bench press, leg press, latissimus pull down, triceps press, biceps curl, shoulder press, and calf raise. All subjects then completed two experimental trials on separate days. The high-intensity trial consisted of one set of five repetitions at 90% of the one-repetition maximum. The low-intensity trial consisted of one set of 15 repetitions at 30% of the one-repetition maximum. This information suggests that ratings of perceived exertion can provide information regarding the intensity of resistance exercise.

Winett et al (2003) determined the effect of low volume resistance and cardiovascular training on strength and aerobic capacity. A randomized control group design was used with 17 unfit males and females (mean age = 37.1 +/- 6.5 year) assigned to an exercise group (n = 9) who performed a progressive cardiovascular graded exercise protocol and resistance training twice a week for 12 weeks or a nonexercising control group (n = 8). The intervention included a graded exercise protocol involving a 3-min warm-up, exercising 3-4 min at 70-80% of maximum heart rate, and a 3-min cool down. The results support a
threshold model and show that time for effective exercise can be substantially reduced.

**Ahtiainen, Pakarinen, Kraemer & Häkkinen (2004)** investigated acute hormonal and neuromuscular responses and recovery in strength athletes versus non-athletes during heavy resistance exercise performed with the forced and maximum repetitions training protocol. Eight male strength athletes (SA) with several years of continuous resistance training experience and 8 physically active but non-strength athletes (NA) volunteered as subjects. These data suggest that, at least in experienced strength athletes, the forced-repetition protocol is a viable alternative to the more traditional maximum-repetition protocol and may even be a superior approach.

**Chromiak et al (2004)** investigated whether post-exercise consumption of a supplement containing whey protein, amino acids, creatine, and carbohydrate combined with a strength training program promotes greater gains in fat-free mass (FFM), muscle strength and endurance, and anaerobic performance compared with an isocaloric, carbohydrate-only control drink combined with strength training. Forty-one males participated in a 4 d/wk, 10-wk periodized strength training program. In conclusion, consumption of a recovery drink after strength
training workouts did not promote greater gains in FFM compared with consumption of a carbohydrate-only drink; however, a trend toward a greater increase in FFM in the supplement group suggests the need for longer-term studies. Performance variables such as muscle strength and endurance and anaerobic performance were not improved when compared with the carbohydrate-only group.

Haykowsky et al (2005) examined the effect that aerobic and strength training have on improving aerobic endurance and muscle strength in female cardiac transplant recipients. 20 female cardiac transplant recipients participated in this investigation. The subjects performed a baseline six-minute walk test and a leg-press strength test when they were discharged following cardiac transplantation. The subjects then participated in a 12-week exercise program consisting of aerobic and lower extremity strength training. Baseline assessments were repeated following completion of the exercise intervention. It was concluded that, aerobic and strength training are effective interventions that can partially restore the impaired aerobic endurance and strength found in female cardiac transplant recipients.
McCurdy, Langford, Doscher, Wiley & Mallard (2005) compared the effects of short-term unilateral resistance training (UL) and bilateral resistance training (BL) with free weights on several tests of unilateral and bilateral lower-body strength and power in men and women. Thirty-eight untrained men and women completed the study. The groups trained 2 days per week for 8 weeks with free weights and 2 days per week for 5 of the 8 weeks with plyometric drills. The resistance-training program consisted of a progression from 3 sets of 15 repetitions at 50% of the subject's predicted 1 repetition maximum (1RM) to 6 sets of 5 repetitions at 87% 1RM. Training volume and intensity were equal for each group. The free-weight squat was used to measure unilateral and bilateral strength. Power was measured by the Magaria-Kalamen stair-climb test and the unilateral and bilateral vertical jump test. It was concluded that, no significant interactions on all tests were found for the men or women comparison between training groups. These results indicate that UL and BL are equally effective for early phase improvement of unilateral and bilateral leg strength and power in untrained men and women.

González-Badillo, Izquierdo & Gorostiaga (2006) examined the effect of 3 volumes of heavy resistance, average
relative training intensity (expressed as a percentage of 1 repetition maximum that represented the absolute kilograms lifted divided by the number of repetitions performed) programs on maximal strength (1RM) in Snatch (Sn), Clean & Jerk (C&J), and Squat (Sq). Twenty-nine experienced (>3 years), trained junior weightlifters were randomly assigned into 1 of 3 groups: low-intensity group (LIG; n = 12), moderate-intensity group (MIG; n = 9), and high-intensity group (HIG; n = 8). All subjects trained for 10 weeks, 4-5 days a week. The present results indicate that short-term resistance training using moderate volumes of high relative intensity tended to produce higher enhancements in weightlifting performance compared with low and high volumes of high relative training intensities of equal total volume in experienced, trained young weightlifters.

Hatfield et al (2006) determined the impact of a very slow (VS) velocity and a self-selected volitional (VOL) velocity at varying intensities on repetition number, peak force, peak power, and total volume in the squat and shoulder press exercises. On separate testing days, 9 resistance trained men performed a squat (SQ) and shoulder press (SP) exercise at 60 or 80% of 1 repetition maximum (1RM) at either VOL or VS (10-second eccentric and 10-second concentric actions) velocity for as many
repetitions as possible. The results of this study indicate that a VS velocity may not elicit appropriate levels of force, power, or volume to optimize strength and athletic performance.

**Hautala et al (2006)** tested the subjects with a poor responsiveness to endurance training might benefit from resistance training in terms of aerobic fitness. The study population consisted of sedentary healthy male and female subjects assigned to either a training (n=73) or a control group (n=18). The randomized cross-over study design included a 2-week laboratory-controlled endurance or resistance training period with a 2-month detraining period between the interventions. In conclusion, the healthy males and females whose training response is low after endurance training seem to result in a marked improvement in their cardio respiratory fitness by resistance training.

**Impellizzeri et al (2006)** compared the effects of specific (small-sided games) vs. generic (running) aerobic interval training on physical fitness and objective measures of match performance in soccer. Forty junior players were randomly assigned to either generic (n=20) or specific (n=20) interval training consisting of 4 bouts of 4 min at 90-95 % of maximum heart rate with 3 min active rest periods, completed twice a
week. The results of this study showed that both small-sided games and running are equally effective modes of aerobic interval training in junior soccer players.

**Kin-Isler & Kosar (2006)** investigated the effects of 10 weeks of step aerobics training on anaerobic performance of men and women. College-age volunteers (64 women and 54 men) were divided into step aerobics (33 women, 27 men) and control (31 women, 27 men) groups. Before and after the 10-week period, the subjects' body composition, muscular strength, Wingate anaerobic performance, and vertical jump anaerobic performance were determined. The step aerobics group participated in step aerobics sessions of 50 minutes per day, 3 days per week for 10 weeks, at 60-80% of their heart rate reserve. It can be concluded that 10 weeks of step aerobics was not effective in improving all of the measured anaerobic indices in men and women.

**Candow & Burke (2007)** determined the effect of short-term equal-volume resistance training with different workout frequency on lean tissue mass and muscle strength. Twenty-nine untrained volunteers (27-58 years; 23 women, 6 men) were assigned randomly to 1 of 2 groups: group 1 (n = 15; 12 women, 3 men) trained 2 times per week and performed 3 sets of 10
repetitions to fatigue for 9 exercises, group 2 (n = 14; 11 women, 3 men) trained 3 times per week and performed 2 sets of 10 repetitions to fatigue for 9 exercises. These results suggest that the volume of resistance training may be more important than frequency in developing muscle mass and strength in men and women initiating a resistance training program.

**Cowley, Swensen & Sforzo (2007)** evaluated the influence of platform (unstable vs. stable, stability ball vs. flat bench) on strength and work capacity during barbell chest-press exercise. We also sought to determine the effects of a barbell chest-press training program performed on a stability ball or flat bench on strength, work capacity, and abdominal power. Fourteen young women (20 - 23 yr) performed a 1 repetition maximum (1RM) barbell chest-press and the YMCA bench press test (YBT) on a stability ball and flat bench, as well as two field tests measuring abdominal power. Thus, the stability ball is an effective platform for barbell chest-press training in untrained women over a short duration.

**Drinkwater et al (2007)** investigated the effect of resistance training. Twelve basketball and 10 volleyball players trained 3 sessions per week for 6 weeks, completing either 4 x 6, 8 x 3, or 12 x 3 (sets x repetitions) of bench press per training
session. Compared with the 8 x 3 group, the 4 x 6 protocol involved a longer work interval and the 12 x 3 protocol involved higher training volume, so each group was purposefully designed to elicit a different number of forced repetitions per training session. In conclusion, there were no significant differences in strength or power gains between groups. In conclusion, when repetition failure was reached, neither additional forced repetitions nor additional set volume further improved the magnitude of strength gains.

Esteve-Lanao, Foster, Seiler & Lucia (2007) compared the effect of 2 training programs differing in the relative contribution of training volume, clearly below vs. within the lactate threshold/maximal lactate steady state region on performance in endurance runners. Twelve subelite endurance runners (who are specialists in track events, mostly the 5,000-m race usually held during spring-summer months and who also participate in cross-country races [9-12 km] during fall and winter months) were randomly assigned to a training program emphasizing low-intensity (subthreshold) (Z1) or moderately high-intensity (between thresholds) (Z2) training intensities. These results provide experimental evidence supporting the value of a relatively large percentage of low-intensity training.
over a long period (approximately 5 months), provided that the contribution of high-intensity training remains sufficient.

**Faigenbaum et al (2007)** evaluated the efficacy of an after-school resistance training program on improving the physical fitness of middle school-age boys. 22 boys (M = 13.9 yr., SD = .4 yr.) participated in a periodized, multiple-set, 9-wk. (2x/week) resistance training program. Statistical analysis indicated that subjects significantly improved performance on the squat (19%), bench press (15%), flexibility (10%), vertical jump (5%), medicine ball toss (12%), and the PACER (36%). Although this design minus a control group limits interpretation, this after-school resistance-training program can improve muscular fitness and cardiovascular fitness in boys and should be replicated with appropriate experimental controls.

**Hill-Haas, Bishop, Dawson, Goodman & Edge (2007)** discussed the effect of altering the rest period on adaptations to high-repetition resistance training is not well known. Eighteen active females were matched according to leg strength and repeated-sprint ability and randomly allocated to one of two groups. One group performed resistance training with 20-s rest intervals between sets, while the other group employed 80-s rest intervals between sets. Both groups performed the same total
training volume and load. Each group trained 3 days a week for 5 weeks [15- to 20-repetition maximum (RM), 2 - 5 sets]. These results suggest that when training volume and load are matched, despite a smaller increase in strength, 5 weeks of training with short rest periods results in greater improvements in repeated-sprint ability than the same training with long rest periods.

**Humburg, Baars, Schröder, Reer & Braumann (2007)** investigated the effects of a 1-set and 3-set strength training program. The subjects were untrained men and women who were randomly signed into 1 of 3 groups: 10 subjects trained during the first 9 weeks (training period 1) with 1 set and 8-12 repetitions per set. After the break (9 weeks), they trained with 3 sets and 8-12 repetitions in training period 2. Twelve subjects started with the 3-set program and continued with the 1-set regime after the break. The control group (n = 7) did not train. In conclusion, depending on the goals of each trainee, these differences between the effects of different strength training volumes indicate that it may be worth spending more time on working out with a 3-set strength training regime.

**Judelson et al (2007)** examined the isolated effect of hydration state on 1) strength, power, and the performance of acute resistance exercise, and 2) central activation ratio (CAR).
Seven healthy resistance-trained males completed three resistance exercise bouts in different hydration states: euhydrated (EU), hypohydrated by approximately 2.5% body mass (HY25), and hypohydrated by approximately 5.0% body mass (HY50). Investigators manipulated hydration status via exercise-heat stress and controlled fluid intake 1 d preceding testing. These data indicate that hypohydration attenuates resistance exercise performance; the role of central drive as the causative mechanism driving these responses merits further research.

Mikkola, Rusko, Nummela, Pollari & Häkkinen (2007) assessed the effects of concurrent explosive strength and endurance training on aerobic and anaerobic performance and neuromuscular characteristics, 13 experimental (E) and 12 control (C) young (16 - 18 years) distance runners trained for eight weeks with the same total training volume but 19% of the endurance training in E was replaced by explosive training. It was concluded that, the concurrent explosive strength and endurance training improved anaerobic and selective neuromuscular performance characteristics in young distance runners without decreases in aerobic capacity, although almost 20% of the total training volume was replaced by explosive
strength training for eight weeks. The neuromuscular improvements could be explained primarily by neural adaptations.

Souza et al (2007) evaluated the effects of 2 modes of aerobic exercise (continuous or intermittent) on maximum strength (1 repetition maximum, 1RM) and strength endurance (maximum repetitions at 80% of 1RM) for lower- and upper-body exercises to test the acute hypothesis in concurrent training (CT) interference. Eight physically active men were submitted to: (a) a graded exercise test to determine strength tests in a rested state (control); and 4 experimental sessions, at least 7 days apart. In conclusion, the acute interference hypothesis in concurrent training seems to occur when both aerobic and strength exercises produce significant peripheral fatigue in the same muscle group.

Alcaraz, Sánchez-Lorente & Blazevich (2008) compared physical performance parameters and cardiovascular load during heavy-resistance circuit (HRC) training to the responses during a traditional, passive rest strength training set (TS). Ten healthy subjects with strength training experience volunteered for the study. Testing was performed once weekly for 3 weeks. On day 1, subjects were familiarized with the test and training exercises.
Thus, HRC sets are quantitatively similar to traditional strength training sets, but the cardiovascular load is substantially greater. HRC may be an effective training strategy for the promotion of both strength and cardiovascular adaptations.

Anderson, Sforzo & Sigg (2008) determined whether combined elastic and free weight resistance (CR) provides different strength and power adaptations than free weight resistance (FWR) training alone. Forty-four young (age 20 +/- 1 years), resistance-trained (4 +/- 2 years’ experience) subjects were recruited from men's basketball and wrestling teams and women's basketball and hockey teams at Cornell University. Subjects were stratified according to team, then randomly assigned to the control (C; n = 21) or experimental group (E; n = 23). Before and after 7 weeks of resistance training, subjects were tested for lean body mass, 1 repetition maximum back squat and bench press, and peak and average power. It was concluded that, training with CR may be better than FWR alone for developing lower and upper body strength, and lower body power in resistance-trained individuals. Long-term effects are unclear, but CR training makes a meaningful contribution in the short term to performance adaptations of experienced athletes.
Chtara et al (2008) examined the influence of the sequence order of high-intensity endurance training and circuit training on changes in muscular strength and anaerobic power. Forty-eight physical education students were assigned to 1 of 5 groups: no training controls (C, n = 9), endurance training (E, n = 10), circuit training (S, n = 9), endurance before circuit training in the same session, (E+S, n = 10), and circuit before endurance training in the same session (S+E, n = 10). Subjects performed 2 sessions per week for 12 weeks. Resistance-type circuit training targeted strength endurance (weeks 1-6) and explosive strength and power (weeks 7-12). It was concluded that, circuit training alone induced strength and power improvements that were significantly greater than when resistance and endurance training were combined, irrespective of the intrasession sequencing.

Davis, Wood, Andrews, Elkind & Davis (2008) evaluated the effects of concurrent strength and aerobic endurance training on muscle strength and endurance, body composition, and flexibility in female college athletes and compared two concurrent exercise (CE) protocols. Twenty-eight women (mean age, 19.6 years) were divided into two matched groups and evaluated before and after a vigorous, 11-week, 3-days per week
CE training program. The results suggest synergy rather than interference between concurrent strength and aerobic endurance training, support prescription of CE under defined conditions, establish the importance of exercise timing and sequence for CE program outcomes, and document a highly effective athletic training protocol.

**Esteve-Lanao, Rhea, Fleck & Lucia (2008)** determined the effects of a running-specific, periodized strength training program (performed over the specific period [8 weeks] of a 16-week macrocycle) on endurance-trained runners' capacity to maintain stride length during running bouts at competitive speeds. Eighteen well-trained middle-distance runners completed the study. In conclusion, periodized, running-specific strength training minimizes the loss of stride length that typically occurs in endurance runners during fatiguing running bouts.

**Machek, Stopka, Tillman, Sneed & Naugle (2008)** examined the effects of a resistance-training program on athletes with intellectual disabilities (ID). 2-way (2 x 2), repeated-measures analysis of variance on 2 groups (males and females); 30 Special Olympics (SO) athletes, age 16-22 (16 males, 14 females). Resistance training, twice per week, for 3 months on
Med-X weight equipment. Exercises tested: chest press, abdominal crunch, seated row, overhead press, seated dip, lower back extension, and biceps curl. It was concluded that, significant strength gains can be accomplished by adolescents with ID via a supervised resistance-training program.

**Mangine et al (2008)** investigated the additive effects of ballistic training to a traditional heavy resistance training program on upper- and lower-body maximal strength. Seventeen resistance-trained men were randomly assigned to 1 of 2 groups: (i) a combined ballistic and heavy resistance training group or (ii) a heavy resistance training group and subsequently participated in an 8-week periodized training program. Training was performed 3 days per week, that is, 6-8 exercises per workout (6-8 traditional exercises for HR; 4-6 traditional + 2 ballistic exercises in COM) for 3-8 repetitions. The results of this study support the inclusion of ballistic exercises into a heavy resistance training program for increasing 1RM bench press and enhancing lower-body power.

**Rana et al (2008)** investigated the effects of a six-week (16-17 training sessions) low velocity resistance training program (LV) on various performance measures as compared to a traditional strength (TS) and a traditional muscular endurance
(TE) resistance training program. Thirty-four healthy adult females (21.1 +/- 2.7 y) were randomly divided into 4 groups: control (C), TS, TE, and LV. Workouts consisted of 3 exercises: leg press (LP), back squat (SQ), and knee extension (KE). Each subject was pre- and post-tested for 1 repetition maximum (1RM), muscular endurance, maximal oxygen consumption (VO2max), muscular power, and body composition. In conclusion, muscular strength improved with LV training however, TS showed a larger improvement. Muscular endurance improved with LV training, but not above what TE or TS demonstrated. For all other variables, there were no significant improvements for LV beyond what C demonstrated.

Shields, Taylor & Dodd (2008) determined whether progressive resistance training improves muscle strength, muscle endurance, and physical function in adults with Down syndrome. Adults (N=20) with Down syndrome (13 men, 7 women; mean age, 26.8 +/- 7.8 y) were randomly assigned through a concealed allocation block randomized method to either an intervention group (n=9) or a control group (n=11). The outcomes measured by blinded assessors were muscle strength (1-repetition maximum [1-RM]), muscle endurance (number of repetitions at 50% of 1-RM) for chest press and leg press, timed
stairs test, and the grocery shelving task. It was concluded that, progressive resistance training is a safe and feasible fitness option that can improve upper-limb muscle endurance in adults with Down syndrome.

Dorgo, King & Rice (2009) investigated the effects of a manual resistance training (MRT) program on muscular strength and endurance and to compare these effects with those of an identically structured weight resistance training (WRT) program. To do this, 84 healthy college students were randomly assigned to either an MRT or WRT group and engaged in a 14-week training program. Each participant's performance was assessed before and immediately after the 14-week training period. Muscular strength was assessed by the one-repetition maximum (1RM) bench press test and the 1RM squat test. Muscular endurance was recorded as the maximum number of repetitions performed with 70% of pretraining 1RM for the bench press and squat exercises. The improvements in muscular strength and muscular endurance after a 14-week MRT program in the present study were similar to those produced by a WRT program, and well-designed MRT exercises seem to be effective for improving muscular fitness.
Gergley (2009) examined the effect of two different modes of lower-body endurance exercise (i.e., cycle ergometry and incline treadmill walking) on lower-body strength development with concurrent resistance training designed to improve lower-body strength (i.e., bilateral leg press 1 repetition maximum [RM]). Thirty untrained participants (22 men and 8 women, ages 18-23) were randomly assigned to one of 3 training groups. This study indicates that the mode of endurance exercise in concurrent training regimens may play a role in the development of strength. Specifically, it seems that cycling is superior to treadmill endurance training for an individual with the goal of developing strength in a multijoint movement (i.e., leg press or squat) in the lower-body because it more closely mimics the biomechanical movement of these exercises.

Sentija, Marsić & Dizdar (2009) explored the influence of an Olympic weight lifting training programme on parameters of aerobic and anaerobic endurance in moderately physically active men. Eleven physical education students underwent a 12-week, 3 times/wk training programme of Olympic weight lifting. Specific exercises to master the lifting technique, and basic exercises for maximal strength and power development were applied, with load intensity and volume defined in relation to
individual maximal load (repetition maximum, RM). The results of this study indicate that changes in both, anaerobic and aerobic endurance due to a 12-wk period of strength training in untrained persons can be determined from a single incremental treadmill test to exhaustion.

**Shaw, Shaw & Brown (2009)** compared the effects of 16 weeks of resistance training and concurrent resistance and endurance training on muscular strength development in 38 sedentary, apparently healthy males (25 yr +/- 8 mo). Subjects were age-matched and randomly assigned to either a control (Con) group (n = 12), resistance training (Res) group (n = 13), or concurrent resistance and endurance training (Com) group (n = 13). As such, concurrent resistance and endurance training does not impede muscular strength gains and can be prescribed simultaneously for the development of strength in sedentary, apparently healthy males and thus may invoke all the physiologic adaptations of resistance and endurance training at once.

**Gonzales & Williams (2010)** determined if sex differences are present in exercise-induced inspiratory muscle function in untrained humans. Eight young untrained women (23.8 ± 1.5 y, VO2max = 33.7 ± 4.0 mL/kg/min) and men (26.1 ± 2.0 y,
VO2max = 36.7 ± 1.2 mL/kg/min) performed high-intensity cycling exercise (80% WRmax) to exhaustion. Inspiratory muscle strength and endurance were assessed pre- and post-exercise by measuring maximal inspiratory pressure (PImax) and time to task failure during a constant-load breathing test (CLBT), respectively. These data demonstrate that women exhibit a greater reduction in inspiratory muscle endurance following an acute bout of high-intensity exercise than men.

**Judge & Burke (2010)** determined the effects of training sessions, involving high-resistance, low-repetition bench press exercise, on strength recovery patterns, as a function of gender and training background. The subjects were 12 athletes (6 males and 6 females) and age-matched college students of both genders (4 males and 4 females). The subjects completed a 3-wk resistance training program involving a bench press exercise, 3 d/wk, to become familiar with the testing procedure. After the completion of the resistance training program, the subjects, on three consecutive weeks, participated in two testing sessions per week, baseline session and recovery session. It was concluded that, for bench press exercises, using different recovery times of 48 h for males and 4 h for females may optimize strength development as a function of gender.
**López-Segovia, Palao Andrés & González-Badillo (2010)** assessed the effect of the training executed by 2 under-19 teams from the first Spanish division on aerobic power, strength, and acceleration capacity. Two under-19 soccer teams that competed in the same league were evaluated on 2 occasions. The first evaluation ($E_1$) was done at the beginning of the competitive period, and the second evaluation ($E_2$) was done 16 weeks later, coinciding with the end of the first half of the regular season. The present study demonstrates that the use of loads as a function of the speed of movement, without the need to determine maximum repetitions is a methodology that is adequate for the improvement of the application of strength in under-19 soccer players.

**Wong, Chaouachi, Chamari, Dellal & Wisloff (2010)** examined the effect of concurrent muscular strength and high-intensity running interval training on professional soccer players' explosive performances and aerobic endurance. Thirty-nine players participated in the study, where both the experimental group (EG, n = 20) and control group (CG, n = 19) participated in 8 weeks of regular soccer training, with the EG receiving additional muscular strength and high-intensity interval training twice per week throughout. Muscular strength training consisted
of 4 sets of 6RM (repetition maximum) of high-pull, jump squat, bench press, back half squat, and chin-up exercises. It was concluded that, high-intensity interval running can be concurrently performed with high load muscular strength training to enhance soccer players' explosive performances and aerobic endurance.

**Studies on Varied Intensities of Interval Training on Physiological Variables**

**Davis & Convertino (1975)** compared results of various training studies are often confounded by use of different indices of exercise intensity. Two frequently used indices are: 1) the % HR max method (exercise at a HR corresponding to a chosen percentage of maximal HR), and 2) this study, % net VO2max was employed as the criterion measure of exercise intensity and a comparison was made between the prediction of % net VO2-MAX by the above two methods. These results suggest that the KM yields a training HR that reflects exercise intensity within reasonable limits of accuracy.

**Hartung, Smolensky, Harrist, Rangel & Skrovan (1977)** compared the effects of various durations of exercise. All subjects trained three days per week at 75% of maximum heart rate. Twenty-nine subjects trained for 6 weeks. Training
durations were 5 min (N = 10), 15 min (N = 10) and 25 min (N = 9) with over 80% of the training sessions consisting of monitored treadmill walking on a grade. The results indicate that at least 15 and preferably 25 min of exercise is necessary to produce optimal endurance improvement with the training intensity and frequency used in this study.

Lesmes, Fox, Stevens & Otto (1978) examined the effects of frequency and distance of high intensity, interval training on females. Thirty-two females participated in an eight-week program of interval run training. Subjects were assigned to either a 2 day/week or a 4 day/week group, as well as a high intensity, short distance (50,101,201 meters), or high intensity longer distance (604, 805, 1208 meters) group. Estimates of training intensity were 170% and 130% Vo2max for the short and longer distance groups, respectively. Maximal and submaximal measures of oxygen consumption (Vo2), heart rate (HR), and venous blood lactic acid were determined prior to and following the training program. It was concluded that the changes in aerobic power and submaximal HR of females are independent of frequency, distance, and intensity of high-intensity interval training programs.
**Denis, Fouquet, Poty, Geyssant & Lacour (1982)** determined the effect of a 40-week training program on the anaerobic threshold (AT) was studied in five subjects (35 +/- 5 yrs). The training program consisted of a bicycle ergometer exercise 1 h per day 3 days a week at a work load corresponding to 80%-85% of VO2 max. Before training (S0) and at the 10th, 20th, 30th, 40th weeks (S10, S20, S30, S40) of the training program, ventilatory AT (AT vent), lactate AT (AT lact), and 4 mmol AT were estimated using a graded exercise test. A part of this paper is devoted to (1) the study of the reproducibility of AT estimation, (2) a comparison to other methods for determining the definition of AT, and (3) the correlations between the three methods utilized for AT estimation.

**Smith & O'Donnell (1984)** determined the effect of 36 weeks endurance training on changes in Vo2 max. Six healthy male subjects followed a programme of endurance training for 36 weeks. At 12 week intervals each underwent an incremental exercise test to maximum on a treadmill. Minute ventilation, cardiac frequency, expired and endtidal concentrations of oxygen and carbon dioxide, oxygen uptake and carbon dioxide output were measured continuously during each test. Anaerobic threshold (AT) was determined non-invasively as the onset of
sustained increases in each of the ventilatory equivalent for oxygen, expired and end-tidal concentrations of oxygen followed by an increase in ventilatory equivalent for carbon dioxide after a brief delay due to isocapnic buffering. A new computerized cumulative-sum method was employed. In conclusion, the improved AT after training is more likely to be related to improved peripheral utilization of oxygen than to an improved oxygen delivery to muscles.

Allen, Freund & Wilmore (1986) analyzed the interaction between a subject's maximal oxygen uptake (VO2max) on an inclined protocol (IP) vs a horizontal protocol (HP) before and after training exclusively on flat terrain. Experimental subjects (E, N = 17) trained by running on flat terrain for 12 wk, 4 d/wk, 37 min/d at an intensity equal to 65 to 85% of their heart rate reserve while control subjects (C, N = 10) remained sedentary. All subjects underwent a minimum of four maximal treadmill tests (two with an IP and two with a HP) prior to training and two maximal treadmill tests (one IP and one HP) post-training. It was concluded that the post-training results do not support the concept of protocol specificity when evaluating VO2max in subjects trained exclusively on flat terrain.
Hardman, Williams & Wootton (1986) evaluated the influence of the training regimen on endurance performance. Endurance was defined as the time to exhaustion at relative exercise intensity of 85% VO2 max. Maximum oxygen uptake was increased by 18% post-training, but endurance at the same absolute work rate as pre-training was increased by more than 200% (32.2 +/- 11.4 min versus 97.8 +/- 27.3 min; P less than 0.01). These improvements were accompanied by changes in the cardiovascular and metabolic responses to standard, submaximum exercise. In conclusion, for short-term cycling training, these findings reinforce the concept of training specificity whilst demonstrating that decrements in sprint performance are not a necessary consequence of improved endurance.

Gardner, Poehlman & Corrigan (1989) compared the effect of endurance exercise training on gross energy expenditure (GEE) during steady-state exercise in 20 younger men (31.2 +/- 0.6 years) and 20 middle-aged men (49.2 +/- 1.1 years). The subjects trained for eight months. The training program consisted of three 45-min walking and jogging exercise sessions per week at an intensity of approximately 60-85% of the heart rate at peak VO2. We administered bicycle ergometer tests at 0,
4, and 8 months into training. We conclude that chronic exercise may modify GEE during a submaximal exercise bout and that this adaptation is similar in magnitude in younger and middle-aged men.

Krzeminski, Miskiewicz, Niewiadomski, Nazar & Kozlowski (1989) determined the effect of endurance training. Eighteen male volunteers (20-23 years) were submitted to 13 weeks of training consisting of 30 min of exercise (at 50%-75% VO2max) on a bicycle ergometer, performed three times a week. Every 4 weeks the heart rate (HR), blood pressure (BP), and systolic time interval (STI) responses to the static handgrip (at 30% MVC) were examined. It is concluded that endurance training of moderate intensity improves cardiac function during static exercise performed with untrained muscles.

McCord, Nichols & Patterson (1989) examined the effects of a 12 week program of low impact aerobic dance conditioning on VO2max, submaximal heart rates and body composition of college-aged women. Sixteen women exercised three times per week for approximately 45 minutes per session at 75-85% of their heart rate reserve. VO2max was measured by indirect calorimetry using a treadmill protocol. Submaximal heart rates were measured by electrocardiography, and body fat was
assessed by hydrostatic weight. All testing was conducted within one week pre- and posttraining. Training sessions consisted of a 5-10 minute warm up, 30-35 minute low impact aerobic dance segment and a 5 minute cool down. It was concluded that low impact aerobic dance is as effective as other endurance training regimens in improving cardiovascular fitness and decreasing body fat.

**Medbø & Burgers (1990)** determined the anaerobic capacity, expressed as the maximal accumulated O2 deficit during treadmill running, of untrained, endurance-trained, and sprint-trained young men. In addition, seven women and five men trained for 6 wk, and their anaerobic capacity was compared before and after the training period. We conclude that the anaerobic capacity varies significantly between subjects and that it can be improved within 6 wk. Moreover, there was a close relationship between a high anaerobic capacity and a high peak rate of anaerobic energy release.

**Weltman et al (1990)** determined the effect of varied intensities endurance training on heart rate. Thirty-one subjects completed a level running treadmill protocol. The mean values at LT, FBLC of 2.0, 2.5, 4.0 mM and max for VO2 were 52.7, 56.4, 58.0, 61.2 and 63.5 ml/kg.min -1, respectively: for velocity they
were 237.4, 252.2, 260.6, 274.4 and 286.5 m/min, respectively; and for HR were 165.7, 172.7, 176.5, 182.3 and 187.4 bts/min, respectively. It was concluded that there was a significant physiological changes takes place due to the effect of varied intensities of endurance training.

Katz, & Wilson (1992) determined the effect of a six week low intensity circuit training. Twenty-six healthy, untrained females were studied to determine the effects of a low-intensity Nautilus circuit training program on resting systolic and diastolic blood pressure. Thirteen subjects who were in good health with no personal history or family history of cardiovascular disease participated in a six-week training program on the Nautilus circuit (14 exercises) and trained at 30% of maximum. Measurements in blood pressure were made before, during (three times per week) and after the study. Another group of 13 females served as controls. An attempt was made to determine if strength increase (due to circuit training) would have an affect on reducing resting systolic and diastolic blood pressure. The investigators concluded that low-intensity, resistive training should not increase blood pressure in white, healthy females, ages 18 to 28 years.
Overend, Paterson & Cunningham (1992) investigated changes in the parameters of aerobic function resulting from continuous training (CT) and interval training of both low power (LPO-IT) and high power output (HPO-IT). Untrained males (n = 17, 25.1 yrs) trained 10 weeks on cycle ergometers (four 40-min sessions a week) at 80% VO2max. Cycle ramp function tests at 0 and 10 weeks were used to determine the four aerobic parameters: VO2max, ventilation threshold (VeT), effective time constant for O2 uptake kinetics (MRT), and work efficiency (eta):

In conclusion. There were no between-group differences; thus neither low power output nor high power output interval training offers an advantage over continuous training of the same average power output in altering the aerobic parameters.

McConell et al (1993) examined the effects of a 4 wk reduction in training volume and intensity in distance runners. Ten well-conditioned males (VO2max = 63.4 +/- 1.3 ml.kg-1 x min-1) underwent 4 wks of base training (BT) at their accustomed training distance (71.8 +/- 3.6 km.wk-1) and intensity (76% of total distance > 70% VO2max). Training volume (-66%), frequency (-50%), and intensity (all running < 70% VO2max) were then decreased for a 4 wk reduced training period (RT). It is concluded that aerobic capacity was maintained in
these runners, despite the combined reduction in training volume and intensity. However, it appears that training intensity during RT is important for the maintenance of 5 km running performance.

**Young et al (1993)** studied the importance of the rise in body temperature during exercise for aerobic capacity adaptations produced by endurance training. The approach used was to compare training effects produced by subjects exercising in hot (35 degrees C) water vs. cold (20 degrees C) water. Thus, exercise-induced body temperature elevations are not an important stimulus for the aerobic adaptations to moderate-intensity endurance training.

**Tabata et al (1996)** evaluated the two training experiments using a mechanically braked cycle ergometer. First, the effect of 6 wk of moderate-intensity endurance training (intensity: 70% of maximal oxygen uptake (VO2max), 60 min.d-1, 5 d.wk-1) on the anaerobic capacity (the maximal accumulated oxygen deficit) and VO2max. In conclusion, this study showed that moderate-intensity aerobic training that improves the maximal aerobic power does not change anaerobic capacity and that adequate high-intensity intermittent training may improve both anaerobic
and aerobic energy supplying systems significantly, probably through imposing intensive stimuli on both systems.

**Bingisser, Kaplan, Scherer, Russi & Bloch (1997)** determined the effect of gender and training on repeatability of cardiopulmonary exercise performance has not been well defined. Therefore, we performed two bicycle exercise tests 1 wk apart in each of two groups: In 19 normal subjects (age 24 to 64 yr, 10 females), with a mean maximal oxygen uptake (VO2max) of 42 mL.kg-1.min-1, who had been in an ongoing training program including bicycle exercise, and in 19 untrained volunteers (23 to 54 yr, 11 females) with a mean VO2max of 36 mL.kg-1.min-1 (P < 0.05). Our study provides normal values for repeatability of various parameters assessed during exercise testing and demonstrates that interpretation of performance during repeated tests has to account for training of the subjects.

**Boulay, Simoneau, Lortie & Bouchard (1997)** clarified whether the intensity at the ventilatory threshold could be sustained during prolonged high-intensity exercise and if the corresponding work rate, pulmonary ventilation, and blood lactate concentration could also be maintained. Fifteen young and healthy male subjects were submitted to a VO2max test on ergocycle and a 90-min high-intensity ergocycle endurance
exercise test. These results show that physiological parameters near the ventilatory threshold are not interchangeable and that some cannot be used to monitor high-intensity long term exercise.

**Tabata et al (1997)** evaluated the magnitude of the stress on the aerobic and the anaerobic energy release systems during high intensity bicycle training, two commonly used protocols (IE1 and IE2) were examined during bicycling. IE1 consisted of one set of 6-7 bouts of 20-s exercise at an intensity of approximately 170% of the subject’s maximal oxygen uptake (VO2max) with a 10-s rest between each bout. In conclusion, this study showed that intermittent exercise defined by the IE1 protocol may tax both the anaerobic and aerobic energy releasing systems almost maximally.

**Grant, Davidson, Aitchison & Wilson (1998)** compared the exercise intensity and rating of perceived exertion (RPE) of a high-impact (HIP) and a low-impact (LIP) university aerobic dance session. Ten women [mean (SD) age 22.9 (2.6) years] took part in the study. An incremental treadmill test was performed by each subject to determine maximum oxygen consumption (VO2max) and maximum heart rate (HRmax). It was concluded that, the exercise intensity elicited by LIP activity may have a
limited training effect for the population utilised in this study, and for some individuals may result in detraining. Conversely, LIP activities may be an appropriate mode of exercise for overweight and unfit individuals.

**Billat, Flechet, Petit, Muriaux & Koralsztein (1999)** determined the effect of interval training in accordance with individual capacities. Eight subjects performed 4 wk of normal training (NT) with one session per week at vVO2max, i.e., five repetitions run at 50% of the time limit at vVO2max, with recovery of the same duration at 60% vVO2max. They then performed 4 wk of overload training (OT) with three interval training sessions at vVO2max. It was concluded that, performance and aerobic factors associated with the performance were not altered by the 4 wk of intensive training at vVO2max despite the increase of plasma nor-adrenaline.

**Carter, Jones, Barstow, Burnley, Williams & Doust (2000)** examined the effect of endurance training on oxygen uptake (VO(2)) kinetics during moderate [below the lactate threshold (LT)] and heavy (above LT) treadmill running. Twenty-three healthy physical education students undertook 6 wk of endurance training that involved continuous and interval running training 3-5 days per week for 20-30 min per session. It
was calculated that only 9-14% of the slow component could be attributed to the change in minute ventilation. We conclude that the VO(2) slow component during treadmill running can be attenuated with a short-term program of endurance running training.

**Helgerud, Engen, Wisloff & Hoff (2001)** studied the effects of aerobic training on performance during soccer match and soccer specific tests. Nineteen male elite junior soccer players, age 18.1 +/- 0.8 yr, randomly assigned to the training group (N = 9) and the control group (N = 10) participated in the study. The specific aerobic training consisted of interval training, four times 4 min at 90-95% of maximal heart rate, with a 3-min jog in between, twice per week for 8 wk. Players were monitored by video during two matches, one before and one after training. In conclusion, enhanced aerobic endurance in soccer players improved soccer performance by increasing the distance covered, enhancing work intensity, and increasing the number of sprints and involvements with the ball during a match.

**James, Barnes, Lopes & Wood (2002)** investigated the effect of exercise on heart rate variability by analysing the heart rate power spectrum prior to, and 1 and 72 h following, an interval training session. Subjects initially performed a graded
test to exhaustion to determine maximal oxygen uptake (VO(2) max) and the running speed at which VO(2) max was first attained (vVO(2) max). The training session was completed on a separate day and comprised six 800 m runs at 1 km x h (-1) below vVO(2) max. Whilst these findings illustrate the importance of controlling the timing of exercise prior to the determination of heart rate variability, the time course of the post-exercise heart rate variability response remains to be quantified.

Laursen, Shing, Peake, Coombes & Jenkins (2002) examined the influence of three different high-intensity interval training (HIT) regimens on endurance performance in highly trained endurance athletes. Before, and after 2 and 4 wk of training, 38 cyclists and triathletes a progressive cycle test to measure peak oxygen consumption (VO(2peak)) and peak aerobic power output (PPO), 2) a time to exhaustion test (T(max)) at their VO(2peak) power output (P(max)), as well as 3) a 40-km time-trial (TT(40)). Subjects were matched and assigned to one of four training groups (G(2), N = 8, 8 x 60% T(max) at P(max), 1:2 work:recovery ratio; G(2), N = 9, 8 x 60% T(max) at P(max), recovery at 65% HR(max); G(3), N = 10, 12 x 30 s at 175% PPO, 4.5-min recovery; G(CON), N = 11). In addition to G(1), G(2), and
G(3) performing HIT twice per week, all athletes maintained their regular low-intensity training throughout the experimental period. The present study has shown that when HIT incorporates P(max) as the interval intensity and 60% of T(max) as the interval duration, already highly trained cyclists can significantly improve their 40-km time trial performance.

**Uusitalo, Laitinen, Väisänen, Länsimies & Rauramaa (2002)** studied the influences of a 1-year controlled, randomized endurance exercise training period on heart rate (HR) and blood pressure variability in a representative sample of Finnish men in their late middle age. Subjects were 140 sedentary men aged 53-63 years. The men were randomized into two identical groups: an intervention (EX) and a reference (CO) group. One hundred and twelve of them remained in the final analysis (EX: n=59, CO: n=53). In conclusion, regular low- to moderate-intensity exercise training could retard the declining tendency in cardiac autonomic nervous function in older men during 1 year.

**An et al (2003)** determined the major gene effects on exercise heart rate (HR) and blood pressure (BP) measured at 50 W and 80 % maximal oxygen uptake (VO (2)max) in 99 White families in the HERITAGE Family Study. Exercise HR and BP were measured both before and after 20 weeks of endurance
training. The baseline phenotypes were adjusted for the effects of age and BMI, whereas the training responses (post-training minus baseline) were adjusted for the effects of age, BMI and the corresponding baseline values, within four sex-by-generation groups. Baseline exercise HR at 50 W was under the influence of a major recessive gene and a multifactorial component, which accounted for 30 % and 27 % of the variance, respectively. In conclusion, submaximal exercise HR at baseline and in response to endurance training was influenced by putative major genes, with no evidence of interactions with sex, age or BMI, in contrast to a multifactorial etiology for exercise BP.

**Coelho, Hamar & Araújo (2003)** compared physiological responses to 2 high-speed resistance training (RT) protocols in untrained adults. Both RT protocols included 12 repetitions for the same 6 exercises, only differing in continuous (1 x 12) or discontinuous (2 x 6) mode. It was concluded that, the discontinuous protocol was significantly less physiologically demanding, although similar or higher CPMP values were obtained.

**Hunter, Seelhorst & Snyder (2003)** compared the cardiovascular and energy expenditure demands of "Super Slow" (SST) and traditional (TT) resistance training 7 resistance-trained
young men (24.3 +/- 3.8 years) had energy expenditure (using indirect calorimetry) and heart rate evaluated during and for 15 minutes after a workout on separate days. Blood lactate levels were also evaluated before and after each intervention. In conclusion, no significant repeated measures analysis main effect was found for either resting energy expenditure or respiratory exchange ratio. The metabolic and cardiovascular stimuli were low with SST. Traditional resistance training increases energy expenditure more than SST does and thus may be more beneficial for body weight control.

Smith, Coombes & Geraghty (2003) compared the effects of two high-intensity, treadmill interval-training programs on 3000-m and 5000-m running performance. Maximal oxygen uptake (\(\text{VO}(2\text{max})\)), the running speed associated with \(\text{VO}(2\text{max})\) (\(\text{v.VO}(2\text{max})\)), the time for which \(\text{v.VO}(2\text{max})\) can be maintained (\(\text{T(max)}\)), running economy (RE), ventilatory threshold (VT) and 3000-m and 5000-m running times were determined in 27 well-trained runners. Subjects were then randomly assigned to three groups; (1) 60% \(\text{T(max)}\), (2) 70% \(\text{T(max)}\) and (3) control. Subjects in the control group continued their normal training and subjects in the two \(\text{T(max)}\) groups undertook a 4-week treadmill interval-training program with the
intensity set at $v.\text{VO}(2\text{max})$ and the interval duration at the assigned $T(\text{max})$. Furthermore, VT and $T(\text{max})$ were significantly higher in the 60% $T(\text{max})$ group post- compared to pre-training. In conclusion, 3000-m running performance can be significantly improved in a group of well-trained runners, using a 4-week treadmill interval training program at $v.\text{VO}(2\text{max})$ with interval durations of 60% $T(\text{max})$.

**Dupont, Akakpo & Berthoin (2004)** determined the effects of in-season, high-intensity interval training on professional male soccer players' running performances were investigated. Twenty-two subjects participated in 2 consecutive training periods of 10 weeks. The first period was considered a control period and was compared with a period where 2 high-intensity interval training exercises were included in the usual training program. Intermittent runs consisted of 12-15 runs lasting 15 seconds at 120% of maximal aerobic speed alternated with 15 seconds of rest. Sprint repetitions consisted of 12-15 all-out 40-m runs alternated with 30 seconds of rest. This study shows that improvements in physical qualities can be made during the in-season period.

**Egaña & Donne (2004)** investigated the metabolic and cardiorespiratory improvements following a 12-week aerobic
training program using elliptical trainer, treadmill or stair-climbing modalities. Twenty-two moderately active females (28.6 +/- 5.3 y, 1.65 +/- 0.05 m) were randomly assigned to treadmill running (n=7), elliptical trainer (n=8) or stair-climber (n=7) groups and trained 3 days x week(-1) initially at 70-80% of maximum heart rate (HRmax) for 30 min, progressing to 80-90% HRmax for 40 min. Subjects performed incremental exercise to volitional exhaustion using an electronically loaded cycle ergometer before and upon completion of the program. In addition, subjects performed sub-maximal fixed load tests at 0, 4, 8 and 12 weeks, using ergometers specific to their exercise group. It was concluded that, in moderately active females similar physiological improvements were observed using stair-climber, elliptical trainer and treadmill running when training volume and intensity were equivalent.

Gething, Passfield & Davies (2004) investigated the relationship between the intensity of an inspiratory muscle training programme and its effect on respiratory muscle strength, exercising heart rate, and ratings of perceived exertion. A total of 66 subjects were randomly assigned to one of three groups. One group trained at 100% of maximum inspiratory pressure (MIP) for 6 weeks (MAX, n=22). A second group
performed 6 weeks of inspiratory muscle training at 80% of MIP (SUB, n=21) and a third control group received no inspiratory training (CON, n=23). It is concluded that 6 weeks of both MAX and SUB training were sufficient to improve inspiratory muscle strength. However, exercising heart rate and perceived exertion decreased with MAX training only.

Seiler & Sjursen (2004) compared running velocity, physiological responses, and perceived exertion during self-paced interval training bouts differing only in work bout duration. Twelve well-trained runners (nine males, three females, 28+/−5 years, VO2 max 65+/−6 mL min(−1) kg(−1)) performed preliminary testing followed by four "high-intensity" interval sessions (Latin squares, 1 session week(−1) over 4 weeks) consisting of 24 x 1, 12 x 2, 6 x 4, or 4 x 6-min running bouts with a 1:1 work-to-rest interval (total session duration 48 min). In conclusion, the optimal interval duration for eliciting a high physiological load is 3-5 min under these training conditions. Increases in RPE during an interval bout are not associated with increasing blood lactate concentration.

Bentley et al(2005) determined the time sustained near VO2max in two interval training (IT) swimming sessions comprising 4x400 m (IT(4x400)) or 16x100 (IT(16xl00)). Elite
swimmers completed three experimental sessions at a 50-m indoor pool over a one week period. The first test comprised a 5 x 200-m incremental test to exhaustion for determination of the pulmonary ventilation threshold (VT, m.s(-1)), VO2max, the velocity associated with VO2max (VO2max, m(s(-1))) and maximum heart rate (HR(max), b.min(-1)). The remaining two tests involved the IT(4x400) and IT(16x100) performed in a randomised order. In conclusion, this factor deserves further research to establish the characteristics of those athletes which influence the physiological responses in IT of short or longer duration repetitions.

**Gurd, Scheuermann, Paterson & Kowalchuk (2005)** examined the effect of prior heavy-intensity warm-up exercise on subsequent moderate-intensity phase 2 pulmonary O2 uptake kinetics (tauVO2) in young adults exhibiting relatively fast (FK; tauVO2 < 30 s; n = 6) and slow (SK; tauVO2 > 30 s; n = 6) VO2 kinetics in moderate-intensity exercise without prior warm up. We conclude that improved muscle perfusion in Mod2 may have contributed to the faster adaptation of VO2, especially in SK; however, a possible role for metabolic inertia in some subjects cannot be overlooked.
Kippelen et al (2005) identified in a follow up study airway changes occurring during the course of a sport season in healthy endurance athletes training in a Mediterranean region. Respiratory pattern and function were analysed in 13 healthy endurance trained athletes, either during a maximal exercise test, or at rest and during recovery through respiratory manoeuvres (spirometry and closing volume tests). The exercise test was conducted on three different occasions: during basic endurance training and then during the precompetition and competitive periods. This study does not provide significant evidence of lung function impairment in healthy Mediterranean athletes after one year of endurance training.

Larsen, Nolan, Borch & Søndergaard (2005) investigated the response to endurance training on physiological characteristics, 10 Nandi town boys and 14 Nandi village boys 16.5 and 16.6 years of age, respectively, from western Kenya performed 12 weeks of running training. The study was performed at altitude (approximately 2000 m.a.s.l. approximately 595 mm Hg). Training heart rate and speed were registered during every training session throughout the entire training period. It is concluded that no difference was observed in trainability with respect to VO2max, running economy,
submaximal heart rate, and submaximal blood lactate and ammonia concentration between Kenyan Nandi town and village boys. The higher performance level of the village boys was likely due to a higher VO2max of these boys.

Laursen, Shing, Peake, Coombes & Jenkins (2005) examined the influence of 3 different high-intensity interval training regimens on the first and second ventilatory thresholds (VT(1) and VT(2)), anaerobic capacity (ANC), and plasma volume (PV) in well-trained endurance cyclists. Before and after 2 and 4 weeks of training, 38 well-trained cyclists (Vo(2)peak = 64.5 +/- 5.2 ml.kg(-1).min(-1)) performed (a) a progressive cycle test to measure Vo(2)peak, peak power output (PPO), VT(1), and VT(2); (b) a time to exhaustion test (T(max)) at their Vo(2)peak power output (P(max)); and (c) a 40-km time-trial (TT(40)). In conclusion, peripheral adaptations rather than central adaptations are likely responsible for the improved performances witnessed in well-trained endurance athletes following various forms of high-intensity interval training programs.

Morton & Cable (2005) determined whether short-term intermittent hypoxic training would enhance sea level aerobic and anaerobic performance over and above that occurring with equivalent sea level training. Over a 4-week period, two groups of
eight moderately trained team sports players performed 30 min of cycling exercise three times per week. One group trained in normobaric hypoxia at a simulated altitude of 2750 m (F(I)O2=0.15), the other group trained in a laboratory under sea level conditions. These data suggest that if there are any advantages to training in hypoxia for sea level performance, they would not arise from the short-term protocol employed in the present study.

**Stojiljković, Mazić, Nesić, Velkovski & Mitrović (2005)** compared changes in running velocity at ventilatory threshold with the velocity at VO2max, before and after the eight-week exercise program. 32 male subjects performed a progressive test for ventilatory threshold (VT) measurement and VO2max on treadmill. After 8 weeks of endurance training (3 times per week, 30 to 70 min, in different zones in respect to the ventilatory threshold) the performed the same test. Comparison between the initial and final test demonstrated a significant increase of observed variables, under experimental conditions: at final test running velocity has increased at ventilatory threshold, in respect to absolute values and expressed as percentage at VO2max.
Duffield, Edge & Bishop (2006) examined the effect of high-intensity interval training on the VO2 response during severe, constant-load exercise. Prior to, and following training, 10 females (VO2 peak 37.4+/-6.0 mL kg-1 min-1) performed a graded exercise test to determine VO2 peak and lactate threshold (LT) and a 6 min cycle test (CT) at the pre-training VO2 peak intensity. Training involved high-intensity intervals (2 min work, 1 min rest) performed 3x week for 8 weeks. In contrast to previous moderate-intensity research, a high-intensity interval training program increased A1 and VO2 EE for the same absolute exercise intensity, decreasing the AOD during a severe-intensity CT.

Schwarz, Urhausen, Schwarz, Meyer & Kindermann (2006) investigated the cardiovascular and metabolic load resulting from different walking intensities derived from maximal velocity (Vmax) during an incremental treadmill walking test. Oxygen uptake, heart rate (HR), blood concentrations of lactate and catecholamines, and rating of perceived exertion were recorded in 16 recreational athletes (mean (SD) age 53 (9) years) during three 30 minute walking trials at 70%, 80%, and 90% of Vmax (V70, V80, and V90) attained during an incremental treadmill walking test. In conclusion, intensity and heart rate
prescriptions for walking training can be derived from an incremental treadmill walking test. The cardiovascular and metabolic reactions observed suggest that V80 is the most efficient workload for training in recreational athletes. Further studies are needed to confirm these findings.

**Daussin et al (2007)** tested the hypothesis that CT and IT might improve peripheral and/or central adaptations, respectively, by randomly assigning 10 healthy subjects to two periods of 24 trainings sessions over 8 weeks in a cross-over design, separated by 12 weeks of detraining. Maximal oxygen uptake (VO2max), cardiac output (Qmax) and maximal arteriovenous oxygen difference (Da-vO2max) were obtained during an exhaustive incremental test before and after each training period. These results suggest that in isoenergetic training, central and peripheral adaptations in oxygen transport and utilization are training-modality dependant. IT improves both central and peripheral components of Da-vO2max whereas CT is mainly associated with greater oxygen extraction.

**Helgerud et al (2007)** compared the effects of aerobic endurance training at different intensities and with different methods matched for total work and frequency. Responses in maximal oxygen uptake (VO2max), stroke volume of the heart
(SV), blood volume, lactate threshold (LT), and running economy (CR) were examined. Forty healthy, nonsmoking, moderately trained male subjects were randomly assigned to one of four groups: 1) long slow distance (70% maximal heart rate; HRmax); 2) lactate threshold (85% HRmax); 3) 15/15 interval running (15 s of running at 90-95% HRmax followed by 15 s of active resting at 70% HRmax); and 4) 4 x 4 min of interval running (4 min of running at 90-95% HRmax followed by 3 min of active resting at 70% HRmax). All four training protocols resulted in similar total oxygen consumption and were performed 3d.wk for 8 wk. In conclusion, high-aerobic intensity endurance interval training is significantly more effective than performing the same total work at either lactate threshold or at 70% HRmax, in improving VO2max. The changes in VO2max correspond with changes in SV, indicating a close link between the two.

**Kiviniemi, Hautala, Kinnunen & Tulppo (2007)** tested utility of heart rate variability (HRV) in daily endurance exercise prescriptions. Twenty-six healthy, moderately fit males were randomized into predefined training group (TRA, n = 8), HRV-guided training group (HRV, n = 9), and control group (n = 9). Four-week training period consisted of running sessions lasting 40 min each at either low- or high-intensity level. TRA group
trained on 6 days a week, with two sessions at low and four at high intensity. Individual training program for HRV group was based on individual changes in high-frequency R-R interval oscillations measured every morning. Increase or no change in HRV resulted in high-intensity training on that day. It was concluded that, no significant differences were observed in the changes of VO(2peak) between the groups. We concluded that cardiorespiratory fitness can be improved effectively by using HRV for daily training prescription.

**Meyer, Auracher, Heeg, Urhausen & Kindermann (2007)** clarified if endurance training effectiveness remains unimpaired when exercise intensity is reduced by a certain amount from "moderate" to "low", but total energy expenditure held constant. For this purpose, 39 healthy untrained subjects (44 +/- 7 yrs, 82 +/- 19 kg; 173 +/- 9 cm) were stratified for endurance capacity and sex and randomly assigned to 3 groups: Training was conducted over 12 weeks and each session monitored by means of portable heart rate (HR) recorders. Identical treadmill protocols prior to and after the training program served for exercise prescription and documentation of endurance effects. It is concluded that within a middle-aged population of healthy untrained subjects, endurance training effectiveness might be
slightly impaired when the training heart rate is chosen 15 bpm lower as compared to moderate intensity, but the total energy output held equal.

**Rozenek, Funato, Kubo, Hoshikawa & Matsuo (2007)** designed to characterize selected physiological responses to short-duration (< or = 60 seconds) interval work performed at velocities corresponding to 100% of vVO2max. Twelve men participated in 3 randomized trials consisting of treadmill running using work (W)/recovery (R) intervals of 15 seconds W/15 seconds R (15/15); 30 seconds W/15 seconds R (30/15); and 60 seconds W/15 seconds R (60/15). Work intervals were performed at 100% of vVO2max, whereas R intervals were performed at 50% of vVO2max. A fourth trial consisting of continuous work (C) at 100% of vVO2max was also performed. It was concluded that, high intensity, short-duration 2:1 W/R intervals appear to produce responses that may benefit both aerobic and anaerobic energy system development. A 4:1 W/R ratio may be an upper limit for individuals in the initial phases of interval training.

**Sirotic & Coutts (2007)** determined the physiological factors that best relate to a generic PHIIR simulation that reflects team sport running activity. The second purpose of this study
was to determine the relationship between common performance tests and the generic PHIIR simulation. Following a familiarization session, 16 moderately trained (VO2max = 40.0 +/- 4.3 ml x kg(-1) x min(-1)) women team sport athletes performed various physiological, anthropometrical, and performance tests and a 30-minute PHIIR sport simulation on a nonmotorized treadmill. We suggest that training programs should focus on improving both LT and Vmax for increasing PHIIR performance in moderately trained women. Future studies should examine optimal training methods for improving these capacities in team sport athletes.

Martinmäki, Häkkinen, Mikkola & Rusko (2008) evaluated the effects of low-dose endurance training on autonomic HR control. We assessed the heart rate variability (HRV) of 11 untrained male subjects (36.8 +/- 7.2 years) at rest and during an incremental maximal aerobic exercise test prior to a 7-week preparatory period and prior to and following a 14-week endurance training period, including a low to high intensity exercise session twice a week. In conclusion, low-dose endurance training enhanced vagal control during exercise, but did not alter resting vagal HR control.
Sporis, Ruzic & Leko (2008) evaluated changes in anaerobic endurance in elite First-league soccer players throughout 2 consecutive seasons, in 2 phases, with and without high-intensity situational drills. Eighteen soccer players were tested before and after the 8-week summer conditioning and again in the next season. The measured variables included 300-yard shuttle run test, maximal heart rate, and maximal blood lactate at the end of the test. During the first phase of the study, the traditional sprint training was performed only 2 x weeks and consisted of 15 bouts of straight-line sprinting. As a result, this study showed some indication that situational high-intensity task training was more efficient than straight-line sprinting in improving anaerobic endurance measured by the 300-yard shuttle run test.

Cesar Mde et al (2009) investigated the effect of local muscle endurance training on maximal oxygen uptake and ventilatory threshold in young women. Nineteen untrained women, ranging in age from 18 to 26 years, were included in the study and assigned to two groups: the control group (n = 10), and the resistance training group (n = 9). The following variables were obtained at baseline and after 12 weeks: body mass; maximal oxygen uptake, maximal heart rate, maximal oxygen
pulse, oxygen uptake at the ventilatory threshold, heart rate at the ventilatory threshold, and oxygen pulse at the ventilatory threshold assessed by cardiopulmonary exercise testing on treadmill; 1-repetition maximum (RM) tests in bench press, latissimus pull down, military press, lying barbell extension, standing barbell curls, leg press, knee extension, and hamstring curl. These findings indicate that the local muscle endurance training realized produces no improvement in cardiorespiratory capacity in young women.

McKay, Paterson & Kowalchuk (2009) examined during high-intensity interval (HIT) and lower-intensity continuous endurance (END) training. Twelve male volunteers underwent eight sessions of either HIT (8-12 x 1-min intervals at 120% maximal O(2) uptake separated by 1 min of rest) or END (90-120 min at 65% maximal O(2) uptake). Subjects completed step transitions to a moderate-intensity work rate (approximately 90% estimated lactate threshold) on five occasions throughout training, and ramp incremental and constant-load performance tests were conducted at pre-, mid-, and posttraining periods. Thus faster kinetics of Vo(2)(p) during the transition to moderate-intensity exercise occurs after only 2 days HIT and END training and without changes to muscle deoxygenation
kinetics, suggesting concurrent adaptations to microvascular perfusion.

**McNicol, O’Brien, Paton & Knez (2009)** compared differences in endurance performance after a training regime where treadmill-running intensity was incrementally elevated to a regime where running intensity remained unchanged. Twenty-eight healthy untrained males and females were randomly and equally assigned into both regimes. The present data show that 20 min treadmill-running sessions performed 3 times a week for 6 weeks improves endurance performance and that progressively elevating exercise intensity is important to maximise improvements in LTVO(2) and LTv.

**Saunders, Pyne & Gore (2009)** evaluated the endurance training at altitude. Over a period of several weeks, one primary acclimatization response is an increase in the volume of red blood cells and consequently of (.)Vo(2max). Altitudes > approximately 2000 m for >3 weeks and adequate iron stores are required to elicit these responses. The substantial reduction in (.)Vo(2max) of athletes at moderate altitude implies that their training should include adequate short-duration (approximately 1 to 2 min), high-intensity efforts with long recoveries to avoid a reduction in race-specific fitness. At the elite level, athlete
performance is not dependent solely on \( V_{O2\text{max}} \), and the "smallest worthwhile change" in performance for improving race results is as little as 0.5%. Consequently, contemporary statistical approaches that utilize the concept of the smallest worthwhile change are likely to be more appropriate than conventional statistical methods when attempting to understand the potential benefits and mechanisms of altitude training.

**Tanisho & Hirakawa (2009)** examined the effects of 2 different training regimens, continuous (CT) and interval (IT), on endurance capacity in maximal intermittent exercise. Eighteen lacrosse players were divided into CT (n = 6), IT (n = 6), and nontraining (n = 6) groups. Both training groups trained for 3 days per week for 15 weeks using bicycle ergometers. Continuous training performed continuous aerobic training for 20-25 minutes, and IT performed high-intensity pedaling comprising 10 sets of 10-second maximal pedaling with 20-second recovery periods. Maximal anaerobic power, maximal oxygen uptake (\( V(O2\text{max}) \)), and intermittent power output were measured before and after the training period. The intermittent exercise test consisted of a set of ten 10-second maximal sprints with 40-second intervals. These results indicated that the endurance capacities for maximal intermittent and continuous
exercises were not identical. Ball game players should therefore improve their endurance capacity with high-intensity intermittent exercise, and it is insufficient to assess their capacity with only V(O2max) or continuous exercise tests.

**Taşkin (2009)** determined the effect of circuit training directed toward motion and action velocity over the sprint-agility and anaerobic endurance. A total of 32 healthy male physical education students with a mean age of 23.92 +/- 1.51 years were randomly allocated into a circuit training group (CTG; n = 16) and control group (CG; n = 16). A circuit training consisting of 8 stations was applied to the subjects 3 days a week for 10 weeks. Circuit training program was executed with 75% of maximal motion numbers in each station. In conclusion, circuit training, which is designed to be performed 3 days a week during 10 weeks of training, improves sprint-agility and anaerobic endurance.

**Clark (2010)** examined improvements in cardiorespiratory fitness (VO(2)) after the use of a mixed-intensity interval endurance-training (MI-ET) program in female soccer players, to validate the MI-ET program as an appropriate training regimen to improve cardiorespiratory fitness (VO(2)) in soccer players. 32 female soccer players (average 18.66 +/- 0.31 years) were
recruited from a group of currently conditioning local U-19 and college soccer teams and randomly assigned to participate in an 8-week periodized training program that involved either the MI-ET program or the continuation of a current endurance-training (ET) program. In conclusion, the MI-ET program is shown to be a valid means to improve aerobic fitness as indicated by the MI-ET group exhibiting significantly greater VO(2) measures after training.

_Cornelissen, Verheyden, Aubert & Fagard (2010)_ investigated the effects of endurance training intensity (1) on systolic blood pressure (SBP) and heart rate (HR) at rest before exercise, and during and after a maximal exercise test; and (2) on measures of HR variability at rest before exercise and during recovery from the exercise test, in at least 55-year-old healthy sedentary men and women. A randomized crossover study comprising three 10-week periods was performed. In the first and third period, participants exercised at lower or higher intensity (33% or 66% of HR reserve) in random order, with a sedentary period in between. Training programmes were identical except for intensity, and were performed under supervision thrice for 1 h per week. In conclusion, in participants at higher age, both training programmes exert
similar effects on SBP at rest, during exercise and during post-exercise recovery, whereas the effects on HR are more pronounced after higher intensity training.

**Ferrauti, Bergermann & Fernandez-Fernandez (2010)** investigated the effects of a concurrent strength and endurance training program on running performance and running economy of middle-aged runners during their marathon preparation. Twenty-two (8 women and 14 men) recreational runners were separated into 2 groups (n = 11; combined endurance running and strength training program [ES]: 9 men, 2 women and endurance running [E]: 7 men and 4 women). The results suggest no benefits of 8-week concurrent strength training for running economy and coordination of recreational marathon runners despite a clear improvement in leg strength, maybe because of an insufficient sample size or a short intervention period.

**Summary of Literature**

The review of literature helped the investigator to spot out relevant topics and variables. Further the literature helped the investigator to frame the suitable hypothesis leading to the problems. The latest literature also helped the investigator to support her findings with regard to the problem. Further the
literature collected in the study will also help the research scholar understanding in the similar areas.

The reviews were presented under the two sections such as studies on the varied intensities of endurance training on physical parameter and physiological parameter with chronological and alphabetical order. All the research studies were presented in the section proves that there is a significant improvement on physical and physiological parameters due to endurance training at various intensities.

The research studies reviewed are from many journals available in the websites such as Pub Med, Science Direct Journals, ERIC websites etc., employ the physical variables such as speed, explosive power, elastic power and cardio respiratory endurance and physiological variables such as resting pulse rate, vital capacity and breath holding time that too among student athletes at college level.

The review of literature helped the researcher from the methodological point of view too. It was learnt that most of the research studies cited in this chapter on the varied intensities of endurance training would effectively improve the various physical and physiological parameter.