CHAPTER II
CHAPTER - II

LITERATURE SURVEY

Literature survey comprises locating, reading and evaluating reports of research as well as reports of casual observation and opinion that are related to the individuals planned research report. A study of relevant literature is an essential step to get a full picture of what has been done with regard to the problem under study. The investigator has made an attempt to bring a brief review of research related to the present study to form the background for the present study and presented the same with appropriate headings.

2.0 STUDIES ON SPORTS SPECIFIC TRAINING

Nikolaosl et.al (2007) to compare a 6-month specific handball training program and a typical physical education program on various strength and jumping skills. The participants (M age = 13.7 years, SD = 1.5) were divided into the Handball Group (n = 51) and the Physical Education Group (n = 70). The Handball Group performed 3 sessions/week (60 min) including ball-handling drills, horizontal and vertical jump-shots, fast-break, and several defensive skills. The Physical Education Group performed the program provided by the Ministry of Education including track and field and other team-sport drills. Analyses of covariance showed that the handball group displayed greater improvement in explosive strength of upper limbs, jumping performance, maximum isometric force of right grip, and 10 m running velocity. These findings showed that handball training can significantly improve preadolescent performance of upper and lower limbs. The inclusion of specific handball drills into the physical education program is recommended.
**Oxyzoglou et.al (2009)** the performance on velocity, agility, and flexibility after six months of specific handball training or a mainstream physical education program was examined in participants (handball, n = 51; physical education, n = 70) who engaged in 3 sessions per week (60 min/session) including ball-handling exercises, horizontal and vertical jump shots, fast breaks, and several defensive skills. Statistically significant differences were observed between the two groups on velocity, agility, and flexibility with differences favouring the handball group. Handball training could significantly improve preadolescents' physical performance.

**Herniman et.al (2006)** the purpose of the study was to determine if six weeks of plyometric training can improve an athlete’s agility. Subjects were divided into two groups, plyometric training and a control group. The plyometric training group performed in a six week plyometric training program and the control group did not perform any plyometric training techniques. All subjects participated in two agility tests: T-test and Illinois Agility Test, and a force plate test for ground reaction times both pre and post testing. Univariate ANCOVAs were conducted to analyze the change scores (post – pre) in the independent variables by group (training or control) with pre scores as covariates. The Univariate ANCOVA revealed a significant group effect F2, 26 = 25.42, p=0.0000 for the T-test agility measure. For the Illinois Agility test, a significant group effect F2, 26 = 27.24, p = 0.000 was also found. The plyometric training group had quicker posttest times compared to the control group for the agility tests. A significant group effect F2, 26 = 7.81, p = 0.002 was found for the Force Plate test. The plyometric training group reduced time on the ground on the posttest compared to the control group. The results of this study show that plyometric training can be an effective training technique to improve an athlete’s agility.

**Stone Nick (2007)** conducted a study on physiological response to sport-specific aerobic interval training in high school male basketball
players. The aim of the present study was to evaluate the effectiveness of a basketball specific endurance circuit on improving measures of aerobic fitness. Methods: Ten male high school basketball players, age 16.4 ± 1.2 years, ranked by fitness level and randomly assigned to a training group (N = 6) or control group (N = 4) participated in the study. The sport-specific aerobic endurance training replaced the fitness component of regular training and was performed during the competitive season. The sport-specific training consisted of interval training using a basketball specific endurance circuit, four times 4 min at 90-95% HRpeak with a 3 min recovery at 60-70% HRpeak, twice per week for 6 weeks. During this time the control group performed regular basketball training. Results: For both the training and control groups the actual mean training intensity for total training duration were 77.4 ± 2.9% HRpeak and 74.1 ± 6.7% HRpeak, respectively. The actual mean training intensity during the work intervals in the training group was 84.1 ± 2.3% HRpeak. There were no clear differences between effects of the two training approaches for measures of maximal oxygen uptake (3.3%; 90% confidence limits, ± 19.3%), running economy (-3.3%; 90% confidence limits, ± 14.2%), repeated sprint ability (0.6%; 90% confidence limits, ± 5.7%) and anaerobic power maintenance during the repeated sprints (-13.7%; 90% confidence limits, ± 49.0%). However, a clear non-trivial effect on sub-maximal heart rate was observed (-7.3%; 90% confidence limits, ± 2.0%) suggesting a beneficial training effect after training. Some evidence for attenuation of speed (-1.8 to -2.8%; 90% confidence limits, ± 3.4 to 5.7%) and power (-1.7%; 90% confidence limits, ± 17.1%) was apparent. Conclusion: Although clear changes in sub-maximal HR responses were observed in the training group, the data in the present study suggests that a basketball specific endurance circuit has little effect on other laboratory and field-based measures of aerobic fitness. In fact, the basketball specific endurance circuit may lead to reduced improvements in jumping and sprinting performances. Further research is
required to clarify the effect of aerobic training approaches on basketball-specific fitness and performance.

2.1 STUDIES ON RESISTANCE TRAINING

Hisacda et. al (1996) conducted a study to assess the influence of two different modes of resistance training in females subject. This study consists of two groups. One group underwent resistance training with low intensity and high volume training and other participated in high intensity and low volume training. The former consisted of sets of 1 – 20 RM with sufficient rest between sets. While the latter consists of 8-9 sets of 4 – 6 RM with go seconds rest in between sets. In both the groups the percentage changes of Isokinetic strength were significantly higher. The result suggests that during the early phase of resistance training two different modes of resistance training may have similar effects on untrained females.

Hetzler et al (1997) have conducted a study on strength and power training in young male Baseball players does not improve functional performance. Two groups of 10 pre-pubescent and pubescent male baseball players trained three times per week for 12 week using a variety of general free weight and machine exercises designed for both strength and power acquisition. For the experienced, notice and control groups respectively the following gains were recorded; leg press -41%, 40 % and 14% and bench press 23%, 18% and 0 %. Both training groups were significantly better than the control group. Similarly the two training groups improved in vertical jump.

Marques et.al (2006) the object of this study was to investigate the changes in physical parameters produced during an in-season resistance training (RT) and detraining (DT, or RT cessation) in 16 high level team handball players (THPs). Apart from normal practice sessions, THPs underwent 12 weeks of RT. Subjects performed 3 sets of 3-6 reps with a load of 70-85% concentric 1 repetition maximum bench press (1RMBP),
3 sets of 3-6 reps with a load of 70-95% of 4 repetition maximum parallel squats (4RMPS), plus vertical jumps and sprints. The 1RMBP, 4RMPS, speed over 30 m (S30), jump (countermovement jump height [CMJ]; CMJ with additional weights [20kg and 40kg], and ball throw velocity (BTv) were tested before the experimental period (T1), after 6 weeks (T2), and after the 12-week experimental period (T3). Immediately after these 12 weeks, THPs started a 7-week DT period, maintained normal practices. The CMJ and the BTv were the only parameters evaluated during DT. The most important gains (p < 0.001) in S30 were obtained between T1-T2 and T1-T3. The BTv improved significantly (p < 0.001) only between T1-T2 and T1-T3. The most relevant increases (p < 0.001) in jumping performance took place between T1-T2 and T1-T3. The 1RMBP showed significant increases (p < 0.001) only between T1-T2 and T1-T3. The 4RMPS increased significantly between all testing trials. After the DT, THPs showed no significant losses in CMJ performance. However, they declined significantly in BTv (p = 0.023). The results suggest that elite THPs can optimize important physical parameters over 12 weeks in-season and that 7 weeks of DT, although insufficient to produce significant decreases in CMJ, are sufficient to induce significant decreases in BTv. It is concluded that after RT cessation THPs reduced BTv performance.

Faigenbaum et.al (2007) the purpose of this study was to compare the effects of a six week training period of combined plyometric and resistance training (PRT, n = 13) or resistance training alone (RT, n = 14) on fitness performance in boys (12-15 yr). The RT group performed static stretching exercises followed by resistance training whereas the PRT group performed plyometric exercises followed by the same resistance training program. The training duration per session for both groups was 90 min. At baseline and after training all participants were tested on the vertical jump, long jump, medicine ball toss, 9.1 m sprint, pro agility shuttle run and flexibility. The PRT group made significantly (p < 0.05) greater
improvements than RT in long jump (10.8 cm vs. 2.2 cm), medicine ball toss (39.1 cm vs. 17.7 cm) and pro agility shuttle run time (-0.23 sec vs. -0.02 sec) following training. These findings suggest that the addition of plyometric training to a resistance training program may be more beneficial than resistance training and static stretching for enhancing selected measures of upper and lower body power in boys.

**Fleck (1999)** the majority of studies examining periodization of weight training have used a traditional strength/power training model of decreasing training volume and increasing training intensity as the program progresses. The majorities of these studies have used males as subjects and do support the contention that periodized programs can result in greater changes in strength, motor performance, total body weight, lean body mass, and percent body fat than non periodized programs. However, studies are needed examining why periodized training is more beneficial than non periodized training. Studies are also needed examining the response of females, children, and seniors to periodized weight-training programs and the response to periodized models other than the traditional strength/power training model.

**Skoufas et.al (2002)** the throwing velocity is an important task that affects substantially the performance of a handball player. Several training methods have been suggested in order to improve this ability. The purpose of this study was to investigate the effect of training with light balls to the throwing velocity of male novice athletes and the effect of a following detraining. The subjects performed 20 weeks of handball training and were divided in two groups: one was using normal handball balls for training and the other 20% lighter ones. The first ten weeks were used for handball players to be familiar with throwing technique. The evaluation tests performed before, in the middle and the end of the specific training period and then after 4 weeks of detraining. The estimation of the throwing velocity was taken out of the mean velocity of 7 shots against a fixed target,
placed 6 meters away from the subjects. A radar gun was used for measuring the ball release velocity. The results showed that training with lighter balls could improve the performance of throwing more than using normal balls. Additionally, the benefit of training was maintained 4 weeks after detraining only for the group that used the lighter ball for training. These findings are in agreement with previous studies that involve similar movements of other sports and suggest that the decreased resistance during training that involves ballistic movements can be advantageous for the player's performance, and therefore, trainers are encouraged to apply this method of training as a tool for improving the efficiency of shooting of novice handball players.

Hoff et.al (2002) to examine the effects of maximal strength training with emphasis on neural adaptations on strength- and endurance-performance for endurance trained athletes. Nineteen male cross-country skiers about 19.7 ± 4.0 years of age and a maximal uptake VO2 \text{max)} of 69.4 ± 2.2 mL x kg⁻¹ x min⁻¹ were randomly assigned to a training group (n =9) or a control group (n = 10). Strength training was performed, three times a week for 8 weeks, using a cable pulley simulating the movements in double poling in cross-country skiing, and consisted of three sets of six repetitions at a workload of 85% of one repetition maximum emphasizing maximal mobilization of force in the concentric movement. One repetition maximum improved significantly from 40.3 ± 4.5 to 44.3 ± 4.9 kg. Time to peak force (TPF) was reduced by 50 and 60% on two different sub maximal workloads. Endurance performance measured as time to exhaustion (TTE) on a double poling ski ergo meter at maximum aerobic velocity, improved from 6.49 to 10.18 min; 20.5% over the control group. Work economy changed significantly from 1.02 ± 0.14 to 0.74 ± 0.10 mL x kg⁰.⁶⁷ x min⁻¹ Maximal strength training with emphasis on neural adaptations improves strength, particularly rate of force development, and improves aerobic endurance performance by improved work economy.
Berger (1963) conducted a study on three groups totaling 48 college student who were trained with progressive resistance exercise for a period of nine weeks three times a week. Each group trained with a different program using the bench press lift. Groups I trained with the 2 – RM for six sets, group – II with the 6-RM for three sets and group – III with the 10 RM for three sets each training session. The 1 – RM for the bench press lift was determined before and after the nine week training period. A comparison was made between groups – II (39-6R and II (3g – 10RI) after nine week of training. In both the studies, group – II had a higher mean then group – III but the mean differences were not significant. In both the studies, group – II has a higher mean than group – III but the mean difference were not significant. In Berger’s study, training continued upto 12 week and at that time the mean of group – II was significant higher than the group – III mean. It is probable that the continuation of the present study to 12 weeks would have resulted in significant differences between groups II and III. The results of this study is that training for nine weeks, three times a weekly with heavy for few repetitions per set and numerous sets is not more effective for improving strength then training with lighter loads for more repetitions per set and fewer sets.

Anderson and Kearney (1982) have conducted a study on resistance training. Three sets of a) high –resistance-low repetition (HL) group (N=15) performed three sets of 6-8 Rm per session: b) medium –resistance-medium-repetition (MM) group (N=16) performed two sets of 30-40 Rm per session: and c) low resistance – high repetition (LH) group (N=12) performed one set of 100-150 Rm, trained three times per week for nine weeks. Strength (1 Rm) absolute and relative endurance were assessed before and after the training period. Low repetitions and high resistances favour strength, whereas moderate to high repetitions using a moderate weight that can be accommodated produce endurance and minor strength changes. It is anticipated that the specificity of these effects will be more
evident the higher the levels and training states of athletes who engage in this type of exercise.

**Tan (1999)** has found that resistance training program variables can be manipulated to specifically optimize maximum strength. After deciding on the exercises appropriate are training intensity (load) and volume. The other factors that are related to intensity are loading form, training to failure, speed of contraction, psychological factors, interest recovery, order of exercise, and number of sessions per day. Repetitions per set, sets per session, and training frequency together constitute training volume. In general, maximum strength is best developed with 1-6 repetition maximum loads, a combination of concentric and eccentric muscle actions, 3-6 maximal sets per session, training to failure for limited periods, long interest recovery time, 3-5 days of training per week and dividing the day’s training into 2 sessions. Variations of the volume and intensity in the course of a training cycle will further enhance strength gains. The increase in maximum strength is affected by neural, hormonal, and muscular adaptations.

**Nakao et.al (1995)** investigated the effects of a long term weight lifting programme characterized by high intensity, low repetition and long rest period between sets on maximal oxygen consumption (VO₂ max) and to determine the advantage of this programme combined with jogging. Male untrained students were involved in weight training for a period of 3 years. The VO₂ max and body composition of the subjects were examined at beginning and 1 year, 2 years (T2) and 3 years after (T3 the training of the group 19 subjects performed the weight lifting programme 5 days each week for 3 years (W – group), 4 subject performed the same weight lifting programme for 3 year with an additional running programme consisting of 2 miles jogging once a week during the 3rd year (R1 – group) and 3 subject performed the weight lifting, programme during the 1st year and the same combined jogging and weight lifting, programme as the RI group during the
2nd and 3rd years (R2 – group). The average VO2 max relative to their body mass of the W – group decrease significantly during the 1st year followed by an insignificant decrease in the 2nd year and a leveling off in the 3rd year. The average VO2 max of the W – group at T2 and T3 was 44.2 and 44.1 1 ml kg – 1 min-1, respectively. The tendency of VO2 max changes in the R, and R2 group was similar to the W – group until they started the jogging programmer, after which they recovered significantly to the initial level within a year of including that programme and they then leveled off during the next year. Lean body mass estimated from skin fold thickness has increase by about 8% after 3 years of weight lifting. The maximal muscles strength, defined by total Olympic lifts (shatch) and clean and jerk) of these three groups increased significantly and there was no significant difference among the amounts of the increase in the three groups.

Goto et al. (2004) studied the acute and long-term effects of resistance-training regimens with varied combinations of high- and low-intensity exercises. Acute changes in the serum growth hormone (GH) concentration were initially measured after 3 types of regimens for knee extension exercise. They were: a medium intensity (approximately 10 repetition maximum [RM]) short interset rest period (30 s) with progressively decreasing load ("hypertrophy type"); 5 sets of a high-intensity (90% of 1RM) and low-repetition exercise ("strength type"); and a single set of low-intensity and high-repetition exercise added immediately after the strength-type regimen ("combi-type"). Post exercise increases in serum GH concentration showed significant regimen dependence: hypertrophy-type > combi-type > strength-type (p < 0.05, n = 8). Next, the long-term effects of periodized training protocols with the above regimens on muscular function were investigated. Male subjects (n = 16) were assigned to hypertrophy/combi (HC) or hypertrophy/ strength (HS) groups and performed leg press and extension exercises twice a week for 10 weeks. During the first 6 weeks, both groups used the
hypertrophy-type regimen to gain muscular size. During the subsequent 4 weeks, HC and HS groups performed combi-type and strength-type regimens, respectively. Muscular strength, endurance, and cross sectional area (CSA) were examined after 2, 6, and 10 weeks. After the initial 6 weeks, no significant difference was seen in the percentage changes of all variables between the groups. After the subsequent 4 weeks, however, 1RM of leg press, maximal isokinetic strength, and muscular endurance of leg extension showed significantly ($p < 0.05$) larger increases in the HC group than in the HS group. In addition, increases in CSA after this period also tended to be larger in the HC group than in the HS group ($p = 0.08$). It was finalized that a combination of high- and low-intensity regimens is effective for optimizing the strength adaptation of muscle in a periodized training program.

2.2. STUDIES ON PLYOMETRIC TRAINING

Jeffery et al. (2000) the purpose of this study was to compare dynamic push-up (DPU) and plyometric push-up (PPU) training programs on 2 criterion measures: (a) the distance achieved on a sitting, 2-handed medicine ball put, and (b) the maximum weight for 1 repetition of a sitting, 2-handed chest press. Thirty-five healthy women completed 18 training sessions over a 6-week period, with training time and repetitions matched for the DPU ($n = 17$) and PPU ($n = 18$) groups. Dynamic push-ups were completed from the knees, using a 2-second-up–2-second-down cadence. Plyometric push-ups were also completed from the knees, with the subjects allowing themselves to fall forward onto their hands and then propelling themselves upward and back to the starting position, with 1 push-up completed every 4 seconds. The PPU group experienced significantly greater improvements than the DPU group on the medicine ball put ($p = 0.03$). There was no significant difference between groups for the chest press, although the PPU group experienced greater increases.
Olasupo (2009) this study determined the comparative effect of three modes of Plyometrics training [depth jumping, rebound jumping and horizontal jumping] on leg muscle strength of untrained University male students. Participants were forty untrained male University students within the age range of 18-27 years. The randomized pretest-posttest control group design was adopted. Subjects were randomly assigned to control group, and three experimental groups based on the types of plyometrics training adopted for the study. The training programme consisted of twelve weeks of interval training administered three times a week. Data collected were analyzed using the mean score, standard deviation and range. Analysis of Covariance [ANCOVA] was used to test for significant differences in the posttest measures among the treatment and control groups using the pretest score variation as covariates. Scheffe’s post hoc analysis was used to determine which of the means were significantly different. All hypotheses for the study were tested at 0.05 critical level. Findings revealed that only the depth jumping and rebound jumping training significantly altered leg muscle strength of subjects (P<0.05). Based on the findings, it was concluded that plyometrics exercises with depth jumping and rebound jumping characteristics are best used in developing muscle strength of the lower extremities.

Robert and Kerry (1994) this study examined the effect of upper body plyometric training, using medicine balls, and upper body conventional weight training on baseball throwing velocity and strength levels as assessed by a 6-RM bench press. Twenty-four junior development baseball players took part in an 8-week training study in conjunction with their baseball training. They were randomly allocated to one of three groups: a medicine ball training group, a weight training group, and a control group. The first group performed explosive upper body medicine ball throws, the weight training group performed conventional upper body weight training, and the control group only performed their normal baseball training. Pre- and post-training
measurements of throwing velocity and 6-RM bench press were recorded. The weight training group produced the greatest increase in throwing velocity and 6-RM strength. The medicine ball group showed no significant increase in throwing velocity but did show a significant increase in strength. For this group of non-strength-trained baseball players, it was more effective to implement a weight training program rather than medicine ball training to increase throwing velocity.

Michael et.al (2006) the purpose of the study was to determine if six weeks of plyometric training can improve an athlete's agility. Subjects were divided into two groups, a plyometric training and a control group. The plyometric training group performed in a six week plyometric training program and the control group did not perform any plyometric training techniques. All subjects participated in two agility tests: T-test and Illinois Agility Test, and a force plate test for ground reaction times both pre and post testing. Univariate ANCOVAs were conducted to analyze the change scores (post – pre) in the independent variables by group (training or control) with pre scores as covariates. The Univariate ANCOVA revealed a significant group effect $F_{2,26} = 25.42, p=0.0000$ for the T-test agility measure. For the Illinois Agility test, a significant group effect $F_{2,26} = 27.24, p = 0.000$ was also found. The plyometric training group had quicker posttest times compared to the control group for the agility tests. A significant group effect $F_{2,26} 7.81, p = 0.002$ was found for the Force Plate test. The plyometric training group reduced time on the ground on the posttest compared to the control group. The results of this study show that plyometric training can be an effective training technique to improve an athlete’s agility

Rahman and Nasar (2005) the purpose of this study was to compare the effects of 3 different training protocols-plyometric training, weight training, and their combination on the vertical jump performance, anaerobic power and muscular strength. Based on their training, forty-eight
male college students were divided into 4 groups: a plyometric training
group (n=13), a weight training group (n=11), a plyometric plus weight
training group (n=14), and a control group (n=10). The vertical jump, the
fifty-yard run and maximal leg strength were measured before and after a
six-week training period. Subjects in each of the training groups trained 2
days per week, whereas control subjects did not participate in any training
activity. The data was analyzed by a 1-way analysis of variance
(repeated-measures design). The results showed that all the training
treatments elicited significant (P< 0.05) improvement in all of the tested
variables. However, the combination training group showed signs of
improvement in the vertical jump performance, the 50 yard dash, and leg
strength that was significantly greater than the improvement in the other 2
training groups (plyometric training and weight training). This study provides
support for the use of a combination of traditional weight training and
plyometric drills to improve the vertical jumping ability, explosive
performance in general and leg strength.

Kin (2006) the purpose of this study was to examine the effects of
plyometric training following a four week training program on vertical jump
height, 40 yard dash, 10 yard dash, and anaerobic power. The subjects
included 17, healthy, male Division 3 hockey players, between the ages of
18-24. All subjects were tested in the vertical jump, 40 yard dash time, 10
yard dash time, and anaerobic power using the Wingate Bike test prior to
starting the plyometric program. The subjects then completed a four week
plyometric training program and were retested. There were significant
differences (p < .05) in the mean anaerobic power drop percentage p = .020,
peak relative power p = .046, peak power p = .005, right foot vertical jump
height (p = .046), left foot vertical jump height (p = .000). The findings
suggested that two days of plyometric training a week for four weeks is
sufficient enough to show improvements in single leg vertical jump height and
overall power endurance. In contrast plyometric training two days a week for
four weeks was not sufficient enough to show improvements in 40 yd dash times, 10 yd dash times, two foot vertical jump height, minimum power (W) values, and relative minimum power (W/kg) values.

**Fletcher and Hartwell (2004)** the purpose of this study was to determine the effect of a combined weights and plyometrics program on golf drive performance. Eleven male golfers' full golf swing was analyzed for club head speed (CS) and driving distance (DD) before and after an 8-week training program. The control group (a = 5) continued formed 2 sessions per week of weight training and plyometrics Controls showed no significant (p 0.05) changes, while experimental subjects showed a significant increase (p 0.05) in CS and DD. The changes in golf drive performance were attributed to an increase in muscular force and an improvement in the sequential acceleration of body parts contributing to a greater initial velocity being applied to the ball. It was concluded that specific combined weights and plyometrics training can help increase CS and DD in club golfers.

### 2.3 Comparison of periodization vs. non-periodization

**Fleck (1999)** the majority of studies examining periodization of weight training have used a traditional strength/power training model of decreasing training volume and increasing training intensity as the program progresses. The majorities of these studies have used males as subjects and do support the contention that periodized programs can result in greater changes in strength, motor performance, total body weight, lean body mass, and percent body fat than non periodized programs. However, studies are needed examining why periodized training is more beneficial than non periodized training. Studies are also needed examining the response of females, children, and seniors to periodized weight-training programs and the response to periodized models other than the traditional strength/power training model.
Willoughby (1993) compared a periodized trained group and a non-periodized trained group that the periodized programme elicited a greater upper body and lower body strength gain for previously weight-trained males. The non-periodized trained with an intensity that was kept constant throughout the 16 week training programme. The periodized group's training programme consisted of four weeks of 5 sets of 10 repetitions (5x10) at 79% of 1 RM, four weeks of 6x8 at 83% of 1 RM, four weeks of 3x6 at 88% of 1 RM and four weeks of 3x4 at 92% of 1 RM. At training weeks of 8, 12 and 16; the periodized training group demonstrated significantly greater improvements in strength levels in the bench press compared to the non-periodized group. For the squat, the periodized group demonstrated a significantly greater strength increases/levels compared to the non-periodized groups at week 16.

In the Kraemer's study (Kraemer et al., 2000), 24 women collegiate tennis players were matched by playing ability and randomly placed into three groups: 1) no resistance control group, 2) single-set circuit resistance training group and 3) periodized multi-set circuit resistance training group. After four, six and nine months of training the periodized training group significantly increased one-repetition maximum strength for bench press, free-weight shoulder-press and leg press. The single-set circuit group only increased strength after the initial 4 months of training. Only the periodized group significantly increased power output ability following nine months of training. Significant increase in serve velocity was observed after four and nine months of training in the periodized group and not in the single-set group. This study shows that sport specific resistance training using periodized training protocol is superior to low-volume single set resistance training in the development of physical abilities.

Rhea (2002) compared linear periodization (LP) and daily undulating periodization (DUP) for strength gains. Twenty men (age = 21 +/- 2.3 years) were randomly assigned to LP (n = 10) or DUP
(n = 10) groups. One repetition maximum (1RM) was recorded for bench press and leg press as a pre-, mid-, and posttest. Training involved 3 sets (bench press and leg press), 3 days per week. The LP group performed sets of 8 RM during weeks 1-4, 6 RM during weeks 4-8, and 4 RM during weeks 9-12. The DUP group altered training on a daily basis (Monday, 8 RM; Wednesday, 6 RM; Friday, 4 RM). Analysis of variance with repeated measures revealed statistically significant differences favoring the DUP group between T1 to T2 and T1 to T3. Making program alterations on a daily basis was more effective in eliciting strength gains than doing so every 4 weeks.

Sale et. al (1990) conducted a study by alternating strength training on one day, with endurance training on the other and compared doing both types of training on the same days per week. Young men (N = 7) experienced strength and endurance training together for two days per week for 20 weeks. A second group (N = 8) performed strength and endurance work two days per week but on different days. Strength training consisted of six to eight bouts of 15-20 RM on a leg press machine. Endurance training consisted of six to eight 3-min bouts on a cycle ergometer at 90-100% VO2max. Both groups improved similarly in strength measures except that the strength-alone training significantly increased the leg press 1 RM more. The reactions to endurance training were similar between the groups with the exception of citrate synthase increased significantly more in the combined training group. Generally, there was little that differed between the groups indicating that the training volume was possibly too low to produce differentiation, although both groups did improve across the duration of the study. Implication made by him was that the mixed and separate strength and endurance training has mainly similar training effects when the volume and frequency of training are low.

Kraemer et al. (2003) compared the physiological and performance adaptations between periodized and non-periodized resistance training in
women collegiate tennis athletes. Thirty women (19 +/- 1 yr) were assigned to either a periodized resistance training group (P), non-periodized training group (NV), or a control group (C). Assessments for body composition, anaerobic power, VO2 (max), speed, agility, maximal strength, jump height, tennis-service velocity, and resting serum hormonal concentrations were performed before and after 4, 6, and 9 months of resistance training performed 2-3 d.wk (-1). Nine months of resistance training resulted in significant increases in fat-free mass, anaerobic power, grip strength, jump height, one-repetition maximum (1-RM) leg press, bench press, and shoulder press, serve, forehand, and backhand ball velocities and resting serum insulin-like growth factor-1, testosterone, and cortisol concentrations. Percent body fat and VO2 (max) decreased significantly in the P and NV groups after training. During the first 6 months, periodized resistance training elicited significantly greater increases in 1-RM leg press (9 +/- 2 vs 4.5 +/- 2%), bench press (22 +/- 5 vs 11 +/- 8%), and shoulder press (24 +/- 7 vs 18 +/- 6%) than the NV group. The absolute 1-RM leg press and shoulder press values in the P group were greater than the NV group after 9 months. Periodized resistance training also resulted in significantly greater improvements in jump height (50 +/- 9 vs. 37 +/- 7%) and serve (29 +/- 5 vs. 16 +/- 4%), forehand (22 +/- 3 vs. 17 +/- 3%), and backhand ball velocities (36 +/- 4 vs. 14 +/- 4%) as compared with non-periodized training after 9 months. The conclusion of the study demonstrated that periodization of resistance training over 9 months was superior for enhancing strength and motor performance in collegiate women tennis players.
2.4 STUDIES ON COMBINED TRAINING

Sale et al. (1990) in their study they compared the responses to doing strength (S) training on alternate days with endurance (E) training Vs doing both types of training on the same days per week, seven young men (group A-2 d) did S and E training together in single sessions 2 d.wk-1 for 20 wk. A second group (B-4 d, N = 8) did the S training on 2 d.wk-1 and E training on 2 other d.wk-1. S training was six to eight sets of 15-20 RM on a leg press weight machine. E training was six to eight 3-min bouts of cycle ergometer exercise at 90-100% VO2max. B-4 d (25%) increased leg press 1 RM more (P less than 0.05) than A-2 d (13%), but the groups increased similarly (A-2 d, B-4 d) in knee extensor (31%, 34%) and flexor (12%, 14%) cross-sectional area and vastus lateralis mean fiber area (33%, 25%). Increases in VO2max (7%, 6%), repetitions with 80% 1 RM (39%, 64%), repetitions with the pre-training 1 RM (33, 55), and PFK (19%, 10%) and LDH (15%, 23%) activity did not differ (P greater than 0.05) between groups. CS activity increased significantly only in A-2 d (26%; B-4 d, 6%). It is concluded that same day (Vs different day) concurrent strength and endurance training may impede strength development without impeding hypertrophy. On the other hand, same day training may enhance increases in CS activity but not VO2max or weight lifting endurance.

Bell et al. (1991) investigated the effects of concurrent endurances and low velocity resistance training (LVR) on measures of strength and aerobic endurance. One group (ES) performed concurrent endurance training 3 days a week and LVR training on alternate days, 3 days a week for 12 weeks. The other group (S) performed only LVR training 3 days a week for 12 weeks without any endurance training. Measurements and increases in training volume were made every three weeks in both groups. Group ES exhibited increases in submaximal exercise responses after 3, 9 and 12 weeks (p less than 0.05). Knee extension peak torque and total work

55
as well as cross-sectional area of quadriceps femoris were significantly increased after 6 and 9 weeks of training in both groups. These findings indicate that no significant differences in strength gains were observed between subjects performing concurrent endurance and resistance training or resistance training only. However, the time-course of adaptations between groups was somewhat different.

Kraemer et al. (2004) examined the adaptations of arm and thigh muscle hypertrophy to different long-term periodized resistance training programs and the influence of upper body resistance training. Eighty-five untrained women (mean age = 23.1 +/- 3.5 yr) started in one of the following groups: total-body training [TP, N = 18 (3-8 RM training range) and TH, N = 21 (8-12 RM training range)], upper-body training [UP, N = 21 (3-8 RM training range) and UH, N = 19, (8-12 RM training range)], or a control group (CON, N = 6). Training took place on three alternating days per week for 24 wk. Assessments of body composition, muscular performance, and muscle cross-sectional area (CSA) via magnetic resonance imaging (MRI) were determined pre-training (T1), and after 12 (T2) and 24 wk (T3) of training. Results of the study were: arm cross-sectional area increased at T2 (approximately 11%) and T3 (approximately 6%) in all training groups and thigh CSA increased at T2 (approximately 3%) and T3 (approximately 4.5%) only in TP and TH. Squat one-repetition maximum (1 RM) increased at T2 (approximately 24%) and T3 (approximately 11.5%) only in TP and TH and all training groups increased 1 RM bench press at T2 (approximately 16.5%) and T3 (approximately 12.4%). Peak power produced during loaded jump squats increased from T1 to T3 only in TP (12%) and TH (7%). Peak power during the ballistic bench press increased at T2 only in TP and increased from T1 to T3 in all training groups. Finally he concluded that training specificity was supported (as sole upper-body training did not influence lower-body musculature) along with the inclusion of heavier loading ranges in a
periodized resistance-training program. This may be advantageous in a total conditioning program directed at development of muscle tissue mass in young women.

Horne et al (1997) carried out a study to determine the effect of concurrent resistance and endurance training on tumor necrosis factor alpha (TNF alpha), urinary free cortisol, strength one-repetition maximum (1 RM), and maximal oxygen consumption (Vo₂max). DESIGN: Randomized control trial of 12 weeks' duration was used. University of Alberta, Edmonton, Alberta, Canada. Forty-five healthy female (n = 18) and male (n = 27) subjects who had not formally trained for at least 6 months prior to the study but were physically active. The mean +/- SD age, height, and body mass for all subjects were 22.3 +/- 3.3 years, 1.76 +/- 9.32 m, and 73.4 +/- 11.6 kg, respectively. The chosen subjects were randomly assigned to four groups: strength training only (S), n = 10; endurance training only (E), n = 11; combined strength and endurance training (SE), n = 13; and a control group (C), n = 10. The S and E groups performed progressively overloaded training sessions three times per week for 12 weeks. The SE group completed the same strength and endurance training programs on different days (i.e., 6 days/week) for 12 weeks. The main outcome measures are: Serum levels of TNF alpha, urinary free cortisol, 1 RM, and Vo₂max were measured before and after 6 and 12 weeks of training. Significant increases in leg press and knee extension 1 RM occurred after training in both S and SE groups, but the relative gains in knee extension 1 RM were greater in the S group. Similar increases in Vo₂max were observed in groups E and SE (p < 0.05). Cortisol was significantly increased in the SE group for women and decreased in the E group for men after training. TNF alpha was significantly elevated in the women of group E after training. No correlation was observed between urinary free cortisol and TNF alpha with training. These results indicate that a partial interference effect of compromised strength gains in unilateral
knee extension of the men occurred after concurrent strength and endurance training that could not be attributed to an interaction between cortisol and TNF alpha in response to this type of exercise.

Leveritt et al. (1999) opined that concurrent strength and endurance training appears to inhibit strength development when compared with strength training alone. The understanding of the nature of this inhibition and the mechanisms responsible for it is limited at present. This is due to the difficulties associated with comparing results of studies which differ markedly in a number of design factors, including the mode, frequency, duration and intensity of training, training history of participants, scheduling of training sessions and dependent variable selection. Despite these difficulties, both chronic and acute hypotheses have been proposed to explain the phenomenon of strength inhibition during concurrent training. The chronic hypothesis contends that skeletal muscle cannot adapt metabolically or morphologically to both strength and endurance training simultaneously. This is because many adaptations at the muscle level observed in response to strength training are different from those observed after endurance training. The observation that changes in muscle fibre type and size after concurrent training are different from those observed after strength training provide some support for the chronic hypothesis. The acute hypothesis contends that residual fatigue from the endurance component of concurrent training compromises the ability to develop tension during the strength element of concurrent training. It is 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.

Bell et al. (2000) investigated the effect of concurrent strength and endurance training on strength, endurance, endocrine status and muscle fibre properties. A total of 45 male and female subjects were randomly assigned to one of four groups; strength training only (S), endurance training only (E), concurrent strength and endurance training (SE), or a control group (C). Groups S and E trained 3 days a week and the SE group trained 6 days a week for 12 weeks. Tests were made before and after 6 and 12 weeks of training. There was a similar increase in maximal oxygen consumption (VO2max) in both groups E and SE (P < 0.05). Leg press and knee extension one repetition maximum (1 RM) was increased in groups S and SE (P < 0.05) but the gains in knee extension 1 RM were greater for group S compared to all other groups (P < 0.05). Types I and II muscle fibre area increased after 6 and 12 weeks of strength training and after 12 weeks of combined training in type II fibres only (P < 0.05). Groups SE and E had an increase in succinate dehydrogenase activity and group E had a decrease in adenosine triphosphatase after 12 weeks of training (P < 0.05). A significant increase in capillary per fibre ratio was noted after 12 weeks of training in group SE. No changes were observed in testosterone, human growth hormone or sex hormone binding globulin concentrations for any group but there was a greater urinary cortisol concentration in the women of group SE and decrease in the men of group E after 12 weeks of training (P < 0.05). These findings would support the contention that combined strength and endurance training can suppress some of the adaptations to strength training and augment some aspects of capillarization in skeletal muscle.

Millet et al. (2002) suggested that endurance training influences the running economy (CR) and the oxygen uptake (VO2) kinetics in heavy exercise by accelerating the primary phase and attenuating the VO2 slow

59
component. However, the effects of heavy weight training (HWT) in combination with endurance training remain unclear. The purpose of this study was to examine the influence of a concurrent HWT+endurance training on CR and the VO(2) kinetics in endurance athletes. Fifteen triathletes were assigned to endurance strength (ES) or endurance-only (E) training for 14 wk. The training program was similar, except ES performed two HWT sessions a week. Before and after the training period, the subjects performed 1) an incremental field running test for determination of VO(2max) and the velocity associated (V(VO2max)), the second ventilatory threshold (VT(2)); 2) a 3000-m run at constant velocity, calculated to require 25% of the difference between VO(2max) and VT(2), to determine CR and the characteristics of the VO(2) kinetics; 3) maximal hopping tests to determine maximal mechanical power and lower-limb stiffness; 4) maximal concentric lower-limb strength measurements. After the training period, maximal strength were increased (P < 0.01) in ES but remained unchanged in E. Hopping power decreased in E (P < 0.05). After training, economy (P < 0.05) and hopping power (P < 0.001) were greater in ES than in E. VO(2max), leg hopping stiffness and the VO(2) kinetics were not significantly affected by training either in ES or E. in conclusion, that they made additional HWT led to improved maximal strength and running economy with no significant effects on the VO(2) kinetics pattern in heavy exercise

McCarty et al. (2002) examined muscle morphological and neural activation adaptations resulting from the interaction between concurrent strength and endurance training. Thirty sedentary healthy male subjects were randomly assigned to one of three training groups that performed 10 wk of 3-d x wk(-1) high-intensity strength training (S), cycle endurance training (E), or concurrent strength and endurance training (CC). Strength, quadriceps-muscle biopsies, computed tomography scans at mid-thigh, and surface electromyogram (EMG) assessments were made before and after
training. S and CC groups demonstrated similar increases (P < 0.0001) in both thigh extensor (12 and 14%) and flexor/adductor (7 and 6%) muscle areas. Type II myofiber areas similarly increased (P < 0.002) in both S (24%) and CC (28%) groups, whereas the increase (P < 0.004) in Type I area with S training (19%) was also similar to the no significant (P = 0.041) increase with CC training (13%). Significant increases (P < 0.005) in maximal isometric knee-extension torque were accompanied by no significant (P <0r= 0.07) increases in root mean squared EMG amplitude of the quadriceps musculature for both S and C groups. No changes (P > 0.38) in the EMG/torque relation across 20 to 100% maximal voluntary contractions occurred in any group. A small 3% increase (P < 0.01) in thigh extensor area was the only change in any of the above variables with E training. Findings indicate 3-d x wk(-1) concurrent performance of both strength and endurance training does not impair adaptations in strength, muscle hypertrophy, and neural activation induced by strength training alone. Results provide a physiological basis to support several performance studies that consistently indicate 3-d x wk (-1) concurrent training does not impair strength development over the short term.

Häkkinen et al. (2003) investigated effects of concurrent strength and endurance training (SE) (2 plus 2 days a week) versus strength training only (S) (2 days a week) in men [SE: n=11; 38 (5) years, S: n=16; 37 (5) years] over a training period of 21 weeks. The resistance training program addressed both maximal and explosive strength components. EMG, maximal isometric force, 1 RM strength, and rate of force development (RFD) of the leg extensors, muscle cross-sectional area (CSA) of the quadriceps femoris (QF) throughout the lengths of 4/15-12/15 (L(f)) of the femur, muscle fibre proportion and areas of types I, IIa, and IIb of the vastus lateralis (VL), and maximal oxygen uptake (VO(2max)) were evaluated. No changes occurred in strength during the 1-week control period, while after the 21-week training period increases of 21% (p<0.001)
and 22% (p<0.001), and of 22% (p<0.001) and 21% (p<0.001) took place in the 1RM load and maximal isometric force in S and SE, respectively. Increases of 26% (p<0.05) and 29% (p<0.001) occurred in the maximum iEMG of the VL in S and SE, respectively. The CSA of the QF increased throughout the length of the QF (from 4/15 to 12/15 L(f)) both in S (p<0.05-0.001) and SE (p<0.01-0.001). The mean fibre areas of types I, IIA and IIb increased after the training both in S (p<0.05 and 0.01) and SE (p<0.05 and p<0.01). S showed an increase in RFD (p<0.01), while no change occurred in SE. The average iEMG of the VL during the first 500 ms of the rapid isometric action increased (p<0.05-0.001) only in S. VO(2max) increased by 18.5% (p<0.001) in SE. The present data do not support the concept of the universal nature of the interference effect in strength development and muscle hypertrophy when strength training is performed concurrently with endurance training, and the training volume is diluted by a longer period of time with a low frequency of training. However, the present results suggest that even the low-frequency concurrent strength and endurance training leads to interference in explosive strength development mediated in part by the limitations of rapid voluntary neural activation of the trained muscles.

Leveritt et al (2003) for their study as subjects twenty-six active university students were randomly allocated to resistance (R, n = 9), endurance (E, n = 8), and concurrent resistance and endurance (C, n = 9) training conditions. Training was completed 3 times per week in all conditions, with endurance training preceding resistance training in the C group. Resistance training involved 4 sets of upper- and lower-body exercises with loads of 4-8 repetition maximum (RM). Each endurance training session consisted of five 5-minute bouts of incremental cycle exercise at between 40 and 100% of peak oxygen uptake (VO2peak). Parameters measured prior to and following training included strength (1RM and isometric and isokinetic [1.04, 3.12, 5.20, and 8.67 rad.s(-1)])
strength), VO2peak and Wingate test performance (peak power output [PPO], average power, and relative power decline). Significant improvements in 1RM strength were observed in the R and C groups following training. VO2peak significantly increased in E and C but was significantly reduced in R after training. Effect size (ES) transformations on the other dependent variables suggested that performance changes in the C group were not always similar to changes in the R or E groups. These ES data suggest that statistical power and dependent variable selection are significant issues in enhancing our insights into concurrent training. It may be necessary to assess a range of performance parameters to monitor the relative effectiveness of a particular concurrent training regimen.

Balabinis et al. (2003) In their study they compared regimens of concurrent strength and endurance training, 26 male basketball players were matched for stature, body composition, and physical activity level. Subjects completed different training programs for 7 weeks, 4 days per week. Groups were as follows: (a) the strength group (S; n = 7) did strength training; (b) the endurance group (E; n = 7) did endurance training; (c) the strength and endurance group (S + E; n = 7) combined strength and endurance training; and (d) the control group (C; n = 5) had no training. The S + E group showed greater gains in Vo(2)max than the E group did (12.9% vs. 6.8%), whereas the S group showed a decline (8.8%). Gains were noted in strength and vertical jump performance for the S + E and S groups. The S + E group had better post training anaerobic power than the S group did (6.2% vs. 2.9%). No strength, power, or anaerobic power gains were present for the E and C groups. We conclude that concurrent endurance and strength training is more effective in terms of improving athletic performance than are endurance and strength training apart.

Nader (2006) stated that strength and endurance training produce widely diversified adaptations, with little overlap between them. Strength training typically results in increases in muscle mass and muscle strength.
In contrast, endurance training induces increases in maximal oxygen uptake and metabolic adaptations that lead to an increased exercise capacity. In many sports, a combination of strength and endurance training is required to improve performance, but in some situations when strength and endurance training are performed simultaneously, a potential interference in strength development takes place, making such a combination seemingly incompatible. The phenomenon of concurrent training, or simultaneously training for strength and endurance, was first described in the scientific literature in 1980 by Robert C. Hickson, and although work that followed provided evidence for and against it, the interference effect seems to hold true in specific situations. At the molecular level, there seems to be an explanation for the interference of strength development during concurrent training; it is now clear that different forms of exercise induce antagonistic intracellular signaling mechanisms that, in turn, could have a negative impact on the muscle's adaptive response to this particular form of training. That is, activation of AMPK by endurance exercise may inhibit signaling to the protein-synthesis machinery by inhibiting the activity of motor and its downstream targets. The purpose of this review is to briefly describe the problem of concurrent strength and endurance training and to examine new data highlighting potential molecular mechanisms that may help explain the inhibition of strength development when strength and endurance training are performed simultaneously.

Mikkola et al. (2007) examined the effects of concurrent endurance and explosive strength training on electromyography (EMG) and force production of leg extensors, sport-specific rapid force production, aerobic capacity, and work economy in cross-country skiers. Nineteen male cross-country skiers were assigned to an experimental group (E, n = 8) or a control group (C, n = 11). The E group trained for 8 weeks with the same total training volume as C, but 27% of endurance training in E was replaced by explosive strength training. The skiers were measured at pre- and post
training for concentric and isometric force-time parameters of leg extensors and EMG activity from the vastus lateralis (VL) and medialis (VM) muscles. Sport-specific rapid force production was measured by performing a 30-m double poling test with the maximal velocity (V(30DP)) and sport-specific endurance economy by constant velocity 2-km double poling test (CVDP) and performance (V(2K)) by 2-km maximal double poling test with roller skis on an indoor track. Maximal oxygen uptake (Vo(2)max) was determined during the maximal treadmill walking test with the poles. The early absolute forces (0-100 ms) in the force-time curve in isometric action increased in E by 18 +/- 22% (p < 0.05), with concomitant increases in the average integrated EMG (IEMG) (0-100 ms) of VL by 21 +/- 21% (p < 0.05). These individual changes in the average IEMG of VL correlated with the changes in early force (r = 0.86, p < 0.01) in E. V(30DP) increased in E (1.4 +/- 1.6%) (p < 0.05) but not in C. The V(2K) increased in C by 2.9 +/- 2.8% (p < 0.01) but not significantly in E (5.5 +/- 5.8%, p < 0.1). However, the steady-state oxygen consumption in CVDP decreased in E by 7 +/- 6% (p < 0.05). No significant changes occurred in Vo(2)max either in E or in C. The present concurrent explosive strength and endurance training in endurance athletes produced improvements in explosive force associated with increased rapid activation of trained leg muscles. The training also led to more economical sport-specific performance. The improvements in neuromuscular characteristics and economy were obtained without a decrease in maximal aerobic capacity, although endurance training was reduced by about 20%.

Valkeinen et al. (2008) examined the effectiveness of concurrent strength and endurance training on muscle strength, aerobic and functional performance, and symptoms in postmenopausal women with fibromyalgia (FM). Randomized controlled trial. Local gym and university research laboratory. Twenty-six women with FM. Progressive and supervised 21-week concurrent strength and endurance training. are Muscle strength of
leg extensors, upper extremities, and trunk; peak oxygen uptake (VO₂ max peak), maximal workload (Wmax), and work time; 10-m walking and 10-step stair-climbing time and self-reported functional capacity (Health Assessment Questionnaire); and symptoms of FM. As results after concurrent strength and endurance training, the groups differed significantly in Wmax (P=.001), work time (P=.001), concentric leg extension force (P=.043), walking (P=.001) and stair-climbing (P<.001) time, and fatigue (P=.038). The training led to an increase of 10% (P=.004) in Wmax and 13% (P=.004) in work time on the bicycle but no change in (VO₂ max) peak. From the results they concluded that Concurrent strength and endurance training in low to moderate volume improves the muscle strength of leg extensors, Wmax, work time, and functional performance as well as perceived symptoms, fatigue in particular. Concurrent strength and endurance training is beneficial to postmenopausal women with FM without adversities, but more extensive studies are needed to confirm the results.

Hickson et al. (1980) examined the consequences of combining resistance and endurance training. It was this study that brought about the idea of an “interference phenomenon,” the concept that somehow endurance training interferes with strength gains when the two types of training are performed simultaneously. Since then, several studies have been published that corroborate the findings.

Kraemer et al. (1980) reported that a group that only resistance trained made greater improvements in maximum leg press, maximum double-leg extension, and lower-body power output compared to a group that concurrently trained. However, numerous other studies have shown no interference in strength gains when concurrent training was compared to resistance training alone.
Gabbett et al (2008) evaluated the efficacy of two different dynamic warm-up conditions, one that was inclusive of open skills (i.e., reactive movements) and one that included only preplanned dynamic activities (i.e., closed skills) on the performance of speed, change of direction speed, vertical jump, and reactive agility in team sport athletes. Fourteen (six male, eight female) junior (mean ± SD age, 16.3 ± 0.7 year) basketball players participated in this study. Testing was conducted on 2 separate days using a within-subjects cross-over study design. Each athlete performed a standardized 7-minute warm-up consisting of general dynamic movements and stretching. After the general warm-up, athletes were randomly allocated into one of two groups that performed a dynamic 15-minute warm-up consisting entirely of open or closed skills. Each of the warm-up conditions consisted of five activities of 3 minute duration. At the completion of the warm-up protocol, players completed assessments of reactive agility, speed (5-, 10-, and 20-m sprints), change of direction speed (T-test), and vertical jump. No significant differences (p > 0.05) were detected among warm-up conditions for speed, vertical jump, change of direction speed, and reactive agility performances. The results of this study demonstrate that either open skill or closed skill warm-ups can be used effectively for team sport athletes without compromising performance on open skill and closed skill tasks.

Chtara et al. (2005) examined the effects of the sequencing order of individualised intermittent endurance training combined with muscular strengthening on aerobic performance and capacity. Forty eight male sport students (mean (SD) age 21.4 (1.3) years) were divided into five homogeneous groups according to their maximal aerobic speeds (vVO₂MAX). Four groups participated in various training programmes for 12 weeks (two sessions a week) as follows: E (n = 10), running endurance training; S (n = 9), strength circuit training; E+S (n = 10) and S+E (n = 10) combined the two programmes in a different order during the same training session. Group C (n = 9) served as a control. All the subjects were evaluated
before (T0) and after (T1) the training period using four tests: (1) a 4 km time trial running test; (2) an incremental track test to estimate \( \dot{V}O_2\text{MAX} \); (3) a time to exhaustion test (\( t_{\text{lim}} \)) at 100% \( \dot{V}O_2\text{MAX} \); (4) a maximal cycling laboratory test to assess \( \dot{V}O_2\text{MAX} \). Training produced significant improvements in performance and aerobic capacity in the 4 km time trial with interaction effect (p<0.001). The improvements were significantly higher for the E+S group than for the E, S+E, and S groups: 8.6%, 5.7%, 4.7%, and 2.5% for the 4 km test (p<0.05); 10.4%, 8.3%, 8.2%, and 1.6% for \( \dot{V}O_2\text{MAX} \) (p<0.01); 13.7%, 10.1%, 11.0%, and 6.4% for \( \dot{V}O_2\text{MAX} (\text{ml/kg}^{0.75}/\text{min}) \) (p<0.05) respectively. Similar significant results were observed for \( t_{\text{lim}} \) and the second ventilator threshold (%\( \dot{V}O_2\text{MAX} \)). Circuit training immediately after individualized endurance training in the same session (E+S) produced greater improvement in the 4 km time trial and aerobic capacity than the opposite order or each of the training programmes performed separately.

Park et al. (2003) investigated the effect of combined aerobic and resistance training on abdominal fat. Our participants in the study consisted of thirty obese women. They were separated into three groups: a control group (n=10), an aerobic training group (n=10) and a combined training group (n=10). The aerobic training group was composed of 60–70% HRmax (intensity), 60 minutes a day (duration) for 6 days a week (frequency). The combined training group was separated into resistance training (3 days a week, Mon, Wed, Fri) and the aerobic training (3 days a week, Tue, Thu, Sat). The levels for abdominal fat volume were measured by determining the subcutaneous fat volume (SFV), visceral fat volume (VFV), and VFV/SFV by CT (computed tomography). The \( \dot{V}O_2\text{max} \) was significantly (p<0.05) increased in both groups. The subcutaneous fat and visceral fat levels were decreased in the combined training group more than in the aerobics training group. Also, the lean body mass (LBM) was significantly increased only in the combined training group. In addition, the
total cholesterol, triglyceride and LDL-C were significantly (p<.05) decreased and the HDL-C was significantly (p<.05) increased in both groups. In conclusion, our results observed that combined training decreased abdominal subcutaneous fat and visceral fat more than aerobic training only.

Chaouachi et al (2009) the objective of this study was to provide anthropometric, physiological, and performance characteristics of an elite international handball team. Twenty-one elite handball players were tested and categorized according to their playing positions (goalkeepers, backs, pivots, and wings). Testing consisted of anthropometric and physiological measures of height, body mass, percentage body fat and endurance ($O_{2\text{max}}$), performance measures of speed (5, 10, and 30 m), strength (bench press and squat), unilateral and bilateral horizontal jumping ability, and a 5-jump horizontal test. Significant differences were found between player positions for some anthropometric characteristics (height and percentage body fat) but not for the physiological or performance characteristics. Strong correlations were noted between single leg horizontal jumping distances with 5-, 10-, and 30-m sprint times ($r = 0.51-0.80; P < 0.01$). The best predictors of sprint times were single leg horizontal jumping with the dominant leg and the distance measured for the 5-jump test, which when combined accounted for 72% of the common variance associated with sprint ability. In conclusion, performance abilities between positions in elite team-handball players appear to be very similar. Single leg horizontal jumping distance could be a specific standardized test for predicting sprinting ability in elite handball players.

Grant et al (2002) the purpose of this investigation was to examine power performance in jump squats when using the complex and contrast training methods. Eleven (n = 11) women participated in a familiarization session and in three randomly ordered testing sessions. One session involved completing sets of power exercises (jump squats) before sets of half
squats (traditional method). The second session involved sets of half squats before sets of jump squats (complex method). A third session involved the alternation of sets of half squats and jump squats (contrast method). No significant difference in jump squat performance between each of the training methods was found. There was a significant difference ($p < 0.05$) in the first set of each session, with the complex method having a significantly lower peak power. Further, there was a significant difference ($p < 0.05$) in performance changes between the higher and lower strength groups, with the higher strength group having a greater improvement in performance using the contrast training method compared with the traditional method. It was concluded that contrast training is advantageous for increasing power output but only for athletes with relatively high strength levels.

**Joseph and Donald (1990)** concurrent strength and endurance training reportedly compromises strength gains and the ability to produce explosive movements. Possible reasons for compromises in strength power adaptations with concurrent training are an increased likelihood of overtraining; differences in the organization of neuromuscular recruitment patterns; alterations in the concentrations of various hormones and differences in activation or repression of various anabolic/catabolic processes at the muscular level; and shifts in protein isozymes such as myosin. Recent research suggests that strength training may enhance endurance performance, although there are reasons to believe that resistance training can also be detrimental. Further research is necessary to determine the extent to which strength adaptations are compromised with concurrent training, and the mechanism(s) by which combined training negatively affects strength. It is recommended that the training of athletes takes into account the physiological demands of the sport and unique needs of the individual athlete in designing a training program in order to optimize performance.
Efstratios et al. (2007) examined the effects of prolonged basketball skills training on maximal aerobic power, isokinetic strength, joint mobility, and body fat percentage, in young basketball players, and controls of the same age. Twenty basketball players and 18 control boys participated in the study. Basketball players participated both in their school's physical education program and in a children's basketball team training program. Controls participated only in their school's physical education program. All subjects were tested every 6 months (18 months total, 11(1/2), 12, 12(1/2), 13 years old) for VO(2)max, peak torque values of the quadriceps and hamstrings at 180 and 300 degrees x s(-1) and range of motion of the knee and hip joints. Body fat percentage was assessed at the beginning and the end of the experimental period. Results showed that the basketball group had lower heart rate values in all ages and higher VO(2) values in the initial test compared with the control in sub maximal intensity. The VO(2) max was altered in both groups on the final test, when compared to the initial test. However, the basketball group had a higher VO(2) max on each of the 6-month follow-up measurements, compared to the control group (p < 0.001). At the end of the 18-month follow-up period no significant differences were observed in isokinetic strength and joint mobility of the lower limbs between the 2 groups. On the contrary, the boys of the trained group had significantly lower percentage body fat values, compared to controls. In conclusion, regular basketball training increased aerobic power and decreased body fat percentage of prepubescent boys, while it did not affect muscle strength and joint mobility of the lower limbs. The major implication suggested by the findings of the present study is that, in order to improve the basic physical components, specific training procedures should be incorporated during the basketball training sessions. It is recommended that all children should be involved in some type of cardiovascular and resistance training program.
**Fleck (1999)** the majority of studies examining periodization of weight training have used a traditional strength/power training model of decreasing training volume and increasing training intensity as the program progresses. The majorities of these studies have used males as subjects and do support the contention that periodized programs can result in greater changes in strength, motor performance, total body weight, lean body mass, and percent body fat than non periodized programs. However, studies are needed examining why periodized training is more beneficial than non periodized training. Studies are also needed examining the response of females, children, and seniors to periodized weight-training programs and the response to periodized models other than the traditional strength/power training model.