The review of related literature is instrumental in the selection of topic, formulation of hypothesis and deductive reasoning to the problem. It helps to get a clear idea and supports the findings with regard to the problem under study.

The literature in any forms the foundation upon which all future work will be built. “The review of literature is generally used as a basis for inductive reasoning for locating and synthesizing all the relevant literature on a particular topic”. The research scholar has gone through the available related literatures, which are relevant to the present study and have been presented in circuit training. 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.

**Ingrid et al (2012)** analyzed the effect of task oriented circuit training compared with usual physiotherapy in terms of self reported walking competency for patients with stroke discharged from a rehabilitation centre to their own home. Patients with stroke who were able to walk a minimum of 10 m without physical assistance and were discharged from inpatient and rehabilitation shifted to an outpatient rehabilitation clinic. Patients were randomly allocated to circuit training or usual physiotherapy, after stratification by rehabilitation centre,
with an online randomization procedure. Patients in the intervention group received circuit training in 90 minute sessions twice a week for 12 weeks. The training included eight different workstations in a gym and was intended to improve performance in tasks relating to walking competency. The control group received usual outpatient physiotherapy. The primary outcome was the mobility domain of the stroke impact scale (SIS, version 3.0). Secondary outcomes were standing balance, self reported abilities, gait speed, walking distance, stair climbing, instrumental activities of daily living, fatigue, anxiety, and depression. Differences between groups were analysed according to the intention to treat principle. All outcomes were assessed by blinded observers in a repeated measurement design lasting 24 weeks. 126 patients were included in the circuit training group and 124 in the usual care group (control), with data from 125 and 117, respectively, available for analysis. One patient from the circuit training group and seven from the control group dropped out. There were no significant differences between groups for the stroke impact scale mobility domain (β=0.05 (SE 0.68), P=0.943) at 12 weeks. Circuit training was associated with significantly higher scores in terms of gait speed (0.09 m/s (SE 0.02), P<0.001), walking distance (20.0 m (SE 7.4), P=0.007), and modified stairs test (−1.6 s (SE 0.7), P=0.015). There were no significant differences between groups for the other secondary outcomes, except for the leisure domain of the Nottingham extended activities of daily living and the memory and thinking domain of the stroke impact scale. With the exception of gait speed (−0.04 m/s (SE 0.02), P=0.040), there were no significant differences between groups at follow-up.
Reddy (2012), compared the Circuit Training Methods on Performance Variables of SC/ST Non-SC/ST Boys. For his study 30 SC/ST students and 30 non-SC/ST students were selected. Then 30 SC/ST students were divided into three groups, named as Continuous Circuit Training Group (CCT), Interval Circuit Training Group (ICT) and Control Group (CT). Another 30 non-SC/ST students were divided into same like SC/ST group. After dividing into six groups, experimental treatments i.e. Continuous Circuit Training Method and Interval Circuit Training Method were applied to CCT and ICT groups only. Criterion measures were 50m run, shuttle run, standing broad jump, cooper’s 12 minutes Run and walk and 800m run for middle distance running performance. Treatments were applied 3 days per week for 8 weeks only. The subjects were tested pre-test and post-test. After collection of Pre-test and Post-test scores I analyzed scored results, collected from different groups by using statistical methods and the results are presented in this article.

Babalola (2011) carried out to examine the responses exhibited by University of Ibadan racket game athletes concerning their physiological and performance characteristics following an 8-week circuit training programme. Multistage sampling technique was used to select 32 participants. The subjects were randomly selected (male and female) from four strata that made-up racket games in the University. Those were: Badminton, Table tennis, Tennis and Squash. The subjects underwent training twice a week, for eight consecutive weeks. A single
group quasi experimental design, otherwise known as repeated measure design was used for the study. Data collected were analyzed using descriptive statistics of mean, range and standard deviation for interpretations of research questions, while inferential statistics of paired t-test was adopted to confirm the significance of the stated hypothesis at the 0.05 level of significance. The results show that there was significant difference in the pretest-posttest responses of physiological variables measured (Resting diastolic and systolic blood pressure RDBP & RSBP, resting heart rate RHR and Body Mass Index BMI). The differences recorded for the performance characteristics of speed and agility was not significant. However, measurements of cardio respiratory endurance, general muscular endurance, arm muscular strength and flexibility showed statistically significant differences. It was recommended that racket games coaches and players should adopt regimental field training programme and engage in strenuous physical training to achieve better body compositions suitable for competitive engagement in their various sports.

Abel et al (2011), compared the aerobic and anaerobic intensities of a circuit-based workout of twenty career firefighters who performed a workout that included 2 rotations of 12 exercises that stressed all major muscle groups. Heart rate was recorded at the completion of each exercise. Blood lactate was measured before and approximately 5 minutes after the workout. The Pre-workout heart rate and post-workout blood lactate responses were statistically compared to data
reported on firefighters performing fire suppression and rescue tasks. The mean circuit-training heart rate was similar to previously reported heart rate responses from firefighters performing simulated smoke-diving tasks (79 ± 5 vs. 79 ± 6% maximum heart rate [HRmax], p = 0.741), but lower than previously reported heart rate responses from firefighters performing fire suppression tasks (79 ± 5 vs. 88 ± 6% HRmax, p < 0.001). The workout produced a similar peak blood lactate compared to that when performing firefighting tasks (12 ± 3 vs. 13 ± 3 mmol·L−1, p = 0.084). In general, the circuit-based workout produced a lower cardiovascular stress but a similar anaerobic stress as compared to performing firefighting tasks. Therefore, firefighters should supplement low-intensity circuit-training programs with high-intensity cardiovascular and resistance training (e.g., ≥85% 1-repetition maximum) exercises to adequately prepare for the variable physical demands of firefighting.

**Abel et al (2011)** evaluated the objective and subjective intensity of a circuit-based strength and conditioning workout designed for firefighters. Twenty career firefighters (mean +/- SD; Height: 1.79 +/- .05 m; Body mass: 95.4 +/- 17.6 kg; BMI: 29.5 +/- 4.7 kg/m2) participated in this study. The workout was composed of a circuit that included 8 externally resisted multi-joint exercises and 4 body weight exercises that stressed all major muscle groups and core musculature. Each participant utilized a self-selected load that allowed for 12 repetitions for the externally resisted exercises. The participants were
allowed 30 seconds to perform each exercise and 30 seconds of rest before beginning the next exercise. One 3 min bout on a stair climber or treadmill was included in the circuit. Two rotations of the circuit were performed. Heart rate was evaluated using a heart rate monitor and was recorded at the completion of each exercise. The participants rated their perceived exertion (RPE) using a 0-10 category-ratio scale after each exercise and at the completion of the workout (i.e., global RPE). Blood lactate was measured before the workout while at rest and approximately 5 min after the completion of the workout. The participants' mean heart rate increased significantly from 80.3 +/- 6.5% of HRmax during the first rotation of the circuit to 86.1 +/- 6.0% of HRmax during the second rotation of the circuit (P < .001). The mean RPE of the individual exercises during the first rotation of the circuit increased significantly from 5.3 +/- 1.5 ("Hard") to 6.5 +/- 1.5 ("Hard"-"Very hard") during the second rotation of the circuit (P < .001). The global RPE was 7.3 +/- 1.2 ("Very hard"). Pre-workout resting blood lactate was 1.5 +/- 0.8 mMol, whereas post-exercise blood lactate increased to 11.8 +/- 3.0 mMol (P < .001). These data indicated that a circuit-based strength and conditioning workout yield similar heart rate and blood lactate values compared to performing tasks on the fire ground. In addition, the 0-10 RPE scale provided a practical way to subjectively set exercise intensity without performing a 1 repetition maximum test.
Alcaraz et al (2011) compared the effects of 8 weeks of high-resistance circuit (HRC) training (3-6 sets of 6 exercises, 6 repetition maximum [RM], ∼35-second inter set recovery) and traditional strength (TS) training (3-6 sets of 6 exercises, 6RM, 3-minute inter set recovery) on physical performance parameters and body composition, 33 healthy men were randomly assigned to HRC, TS, or a control group. Training consisted of weight lifting 3 times a week for 8 weeks. Before and after the training, 1RM strength on bench press and half squat exercises, bench press peak power output, and body composition (dual x-ray absorptiometry) were determined. Shuttle run and 30-second Wingate tests were also completed. Upper limb (UL) and lower limb 1RM increased equally after both TS and HRC training. The UL peak power at various loads was significantly higher at post-training for both groups (p ≤ 0.01). Shuttle-run performance was significantly better after both HRC and TS training, however peak cycling power increased only in TS training (p ≤ 0.05). Significant decreases were found in % body fat in the HRC group only; HRC and TS training both resulted in an increased lean but not bone mass. The HRC training was as effective as TS for improving weight lifting 1RM and peak power, shuttle-run performance and lean mass. Thus, HRC training promoted a similar strength-mass adaptation as traditional training while using a shorter training session duration.

Hofstetter et al (2011) implemented an outdoor circuit training program as an addition to standard training and to examine its effects on physical fitness and injury incidence rate in Swiss Army recruits. An intervention group (standard and additional training, n = 134, 21.0 +/-
1.1 years, 74.1 +/- 10.0 kg and 1.78 +/- 0.1 m) and a control group (standard training only, n = 125, 20.4 +/- 1.2 years, 73.3 +/- 9.1 kg and 1.78 +/- 0.1 m) from the same fusilier infantry training school were compared. Physical standard training in the Swiss Army is specified to two sessions with a total duration of at least three hours per week. Groups of 20 to 50 recruits underwent these trainings in a gym hall and outdoors. Standard training included a wide range of exercises and sport activities (strength and aerobic fitness training, team sports, obstacle courses, physical fitness tests, and orienteering). The additional circuit fitness training program implemented in this study was conducted once a week for 60 minutes. It was performed outdoors and consisted of the same exercises every week (warm-up, squats, prone bridge, back/shoulder exercise, stair climbing, Side Bridge, single leg balance, walking on a balance beam, intermittently running, and active recovery). Volunteers’ physical fitness was assessed during the first and last weeks of basic military training (7 weeks) using a standing long jump, seated 2-kg shot put, one-leg standing test (OLS), trunk muscle strength test (TMS), and progressive endurance run (PER). Injury data were collected in medical records for 21 weeks of military training school. The intervention group performed 1.0 session of standard training for 70.0 minutes and 1.0 session of additional outdoor circuit training for 50.0 minutes per week. The control group performed 1-3 sessions of standard training for a total of 70.7 minutes per week. After the seven-week basic military training, the intervention
and the control groups showed significant improvements in OLS (35.63 and 9.79%), TMS (29.84 and 11.31%), PER (15.64 and 16.37%), and total physical fitness score (12.04 and 7.78%, p < 0.05). The intervention group showed significantly greater improvements in OLS, TMS, and total physical fitness scored more than the control group (p < 0.05). No significant differences in injury incidence rate between the two study groups (intervention group: 14.2, control group: 13.9 injuries/month/100 persons) was registered. The results indicated that the change from a civilian daily routine to the physically more demanding military routine led to significant improvements in physical fitness in both the study groups. The additional outdoor circuit training session per week led to greater improvements in total physical fitness score, but did not increase injury rates.

Takahashi, (2011), examined the effects of learning trials on young healthy untrained males' self-selected loads for eight commonly used exercises, during the circuit weight training. Self-selected loads after the subjects experienced the imposed 60% of 1RM (repetition maximum) learning trial and the subjects experienced the RPE (ratings of perceived exertion) learning trial were examined. Twenty-one untrained healthy college-aged male subjects (mean age +/- SD = 21.43 +/- 2.29 years) were recruited from the University of Nebraska-Lincoln campus community. Prior to the experimental sessions, the subjects participated in a familiarization session to learn the operation of eight selectorized machines arranged in a circuit fashion, at a cadence of 40 beats/minute, and in using an OMNI-RPE scale chart to rate their
perceived exertion. The subjects’ OMNI RPE-AM (active muscle) of 6 (somewhat hard) weights and the subjects’ 60% of their 1RM for each exercise were used for their separate learning trials. After each learning trial was completed, the subjects subsequently self-selected weights that they believed would improve their muscular fitness. A 2 (groups) X 5 (selected weights) MANOVA with repeated measures revealed that there were significant (\(\lambda = 0.10, F = (32, 256.06) = 6.95, p \leq 0.001\), partial \(\eta^2 = 0.44\)) differences among pre-self-selected weights (Pre SS weights), post-60% of 1RM learning trial self-selected weights (Post SS weights A), and post-RPE 6 learning trial self-selected weights (Post SS weights B). Follow-up univariate analysis revealed that the learning effects made significant (p < 0.001) contributions to all exercises of the selected weight scores. Pair wise comparisons for the selected weights were further analyzed to determine which variable was significantly different from others. All eight exercises’ Post SS weights A were significantly heavier than those of Pre SS weights. In addition, all eight exercises’ Post SS weights A were significantly heavier than those of Post SS weights B, except the rowing exercise. The result indicated that if an untrained male undergoes a circuit weight training program for the first time it will be beneficial for him to experience imposed relatively higher intensity (i.e., 60% of 1RM) specific to the exercises that would be performed during his orientation or learning trial.

**Rahimi (2011)** investigated the effects of an acute bout of resistance exercise (RE) on oxidative stress response and oxidative DNA damage in male athletes and whether supplementation with Cr could negate any observed differences. Twenty-seven resistance-trained men
were randomly divided into a Cr supplementation group (the Cr group [21.6 ± 3.6 years], taking 4×5 g Cr monohydrate (per day) or a placebo (PL) supplementation group (the PL group [21.2 ± 3.2 years], taking 4 × 5 g maltodextrin (per day). A double-blind research design was employed for a 7-day supplementation period. Before and after the seventh day of supplementation, the subjects performed an RE protocol (7 sets of 4 exercises in 60–90 sec. (1 repetition maximum) in the flat pyramid loading pattern. Blood and urine samples taken before, in the course of training period, and 24-hour post exercise, were analyzed for plasma malondialdehyde (MDA) and urinary 8-hydroxy-2-deoxyguanosine (8-OHdG) excretion. Before the supplementation period, a significant increase in the urinary 8-OHdG excretion and plasma MDA level was observed after RE. The Cr supplementation induced a significant increase in athletics performance, and it attenuated the changes observed in the urinary 8-OHdG excretion and plasma MDA. These results indicated that Cr supplementation reduced oxidative DNA damage and lipid peroxidation induced by a single bout of RE.

*Hazley et al* (2010), evaluated the effects of an 8-week, low frequency, hospital-based resistance training programme on metabolic risk factors in type 2 diabetic patients. Participants were self-selected into either an 8-week resistance training programme or a control group. Anthropometric indices, fasting glucose, HbA1c, total cholesterol, HDL and LDL lipoproteins, triglycerides, fasting insulin, and insulin
sensitivity were assessed at baseline and 8 weeks later. Six participants were recruited (age 53 ± 9 years; BMI 32 ± 3 kg·m\(^{-2}\)), and a further six participants acted as controls (age 55 ± 9 years; BMI 31 ± 3 kg·m\(^{-2}\)). After training, waist circumference and waist-to-hip ratio were significantly reduced, with no associated changes in the control group. Metabolic risk factors remained unchanged following training (\(P > 0.05\)). He concluded that an 8-week, low frequency, resistance training programme reduced abdominal fat content but had little impact on metabolic risk factor modification in type 2 diabetics.

Reddy and Reddy (2010), compared the effect of Plyometric Training, Circuit Training and Combined Training on selected fitness components among secondary students. Four different untrained school Boys of Ekashila High School Warangal in the age group of 14-15 years those who have not participated intensively in games and sports or any special coaching programme were used for the purpose of the study. However they were allowed to attend the regular physical education classes in school. So, 40 students were selected randomly by lot from the total population of 300 subjects after eliminating physically handicapped students. Then they were randomly divided into four equal groups consisting of 10 subjects in each group. The groups were named by lot as Plyometric Training group, Circuit Training group, Combined training group and Control group and their performances were measured before and after 12-weeks of Training. In Plyometric Training eight exercises and (four for Upper body and four for lower
body) in circuit Training eight exercises were used. The combined Training group subjects were asked to join with the Plyometric Training group on Tuesday, Thursday, Saturday & Monday, Wednesday and Friday with Circuit Training group. The control group did not participate in any Training programme except their routine activities. The ‘t’ test and Anacova were used to find out the training effect and to compare the Training effect respectively. Circuit Training group showed better performance than other groups.

Taskin(2009) determined the effect of circuit training directed towards 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. The FIFA Medical Assessment and Research Centre (F-MARC) test battery, which was designed by FIFA, was used for measuring sprint-agility and anaerobic endurance. Pre and post training testing of participants included assessments of sprint-agility and anaerobic endurance. Following the training, there was a significant \( p < 0.05 \) difference in sprint-agility between pre- and post testing for the CTG (pretest = 14.76 ± 0.48 seconds, posttest = 14.47 ± 0.43 seconds). Also, there was a significant \( p < 0.05 \) difference in anaerobic endurance between pre and post testing for the CG (pretest = 31.53 ± 0.48 seconds, posttest = 30.73 ±
0.50 seconds). 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.

*Camargo et al (2008)* compared the effects of aerobic training and CWT upon morphological and functional cardiac adaptations detected by magnetic resonance imaging. For this study twenty healthy sedentary individuals were randomly assigned to participate in a 12-week programme of aerobic training (n = 6), CWR (n = 7) or no intervention (n = 7, controls). Training programmes consisted of 36 sessions, 35 min each, 3 times per week, at 70% of maximal heart rate, and CWT included series of resistance exercises performed at 60% of 1 maximal repetition. Cardiopulmonary exercise testing and cardiac magnetic resonance imaging were performed before and after the intervention. There was a similar improvement in VO(2)peak following aerobic training (mean (SD) increment: 12 (4)% and CWT (12 (4)%), while there was no change in the control group. Aerobic training (12 (6)%) and CWT (16 (5)%) improved strength in the lower limbs, and only CWT resulted in improvement of 13 (4)% in the strength of the upper limbs. However, there were no detectable changes in left ventricular mass, end-diastolic volume, stroke volume or ejection fraction. In previously sedentary individuals, short-term CWT and aerobic training induce similar improvement in functional capacity without any adaptation in cardiac morphology detectable by cardiac magnetic resonance imaging.
Brentano (2008) analyzed the effects of high-intensity ST and circuit training on isometric strength (IS), upper limb dynamic strength (ULS) and lower limb dynamic strength (LLS), muscle activation of quadriceps (EMGquad), maximal oxygen uptake ([\(\text{V}_{\text{O}}\text{2max}\)]), time to exhaustion (TE), and bone mineral density (BMD). Twenty-eight postmenopausal women were divided into 3 groups: 1) ST group (STG, n = 9, 45-80% 1 repetition maximum (1RM), 2-4 sets, 20-6 reps), 2) circuit training group (CTG, n = 10, 45-60% 1RM, 2-3 sets, 20-10 reps), and 3) a control group (CON, n = 9, no exercise). Significant level was defined as p <= 0.05 for all analyses. After 24 weeks of training, increases were observed in STG and CTG. However, whereas in the STG, the IS (32.7%), ULS (28.7%), LLS (39.4%), EMGquad (50.7%), [\(\text{V}_{\text{O}}\text{2max}\)] (22%), and TE (19.3%) increased, CTG showed changes only in IS (17.7%), ULS (26.4%), LLS (42.2%), [\(\text{V}_{\text{O}}\text{2max}\)] (18.6%), and TE (16.8%). BMD did not change in any experimental group. In the conclusion, there were no changes in the variables analyzed. The results suggested that ST and circuit training positively affect postmenopausal women's muscular strength, muscular activation, and cardiorespiratory fitness, with no changes in BMD.

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 (ages, 21.4 +/- 1.3 years) were assigned to
1 to 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). Endurance training sessions included 5 repetitions run at the velocity associated with \[\text{V_{o2max}}\] for a duration equal to 50% of the time to exhaustion at \[\text{V_{o2max}}\]; recovery was for an equal period at 60% \[\text{V_{o2max}}\]. Maximal strength in the half squat, strength endurance in the 1-leg half squat and hip extension, and explosive strength and power in a 5-jump test and countermovement jump were measured pre- and post-testing. No significant differences were shown following training between the S+E and E+S groups for all exercise tests. However, both S+E and E+S groups improved less than the S group in 1 repetition maximum (p < 0.01), right and left 1-leg half squat (p < 0.02), 5-jump test (p < 0.01), peak jumping force (p < 0.05), peak jumping power (p < 0.02), and peak jumping height (p < 0.05). The intrasession sequence did not influence the adaptive response of muscular strength and explosive strength and power. 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.
Tarin (2008) determined the effect of a 6-week circuit weight training program on levels of physical activity enjoyment and fitness among previously sedentary middle-aged women. Ten women, between the age group of 31 to 51 years old, were assessed for physical fitness (curl up test, push up test, and step test) and given the Physical Activity Enjoyment Scale (PACES). Participants completed 6 weeks of progressive circuit weight training, 2 days a week for 60 minutes each day. The circuit consisted of 10 stations with cardiovascular and muscular endurance exercises. A 1 (group) x 8 (time) repeated measures ANOVA with follow-up pair wise comparisons was used to determine if there were significant (p < .05) differences in the PACES score. Results indicated a significant (p < .05) increase in PACES scores from the pretest (85.80 +/- 19.95) to the posttest (102.10 +/- 15.19). Results were also significantly greater at week 1, 2 and 6. Three simple 1 (group) x 2 (time) ANOVAs were used to determine any differences for the fitness variables. The results indicated significantly (p < .05) greater scores for upper body and abdominal muscular endurance, but no significant (p < .05) difference in recovery heart rate. These results indicate a relatively brief physical activity program can increase physical activity enjoyment and fitness levels among a sedentary middle-aged female population.

Adeniji (2007) examined the comparative effects of Circuit training Programme on Speed and Power to Pre and Post-Menarcheal girls. A pre-test post-test control group, experimental design was used to carry out the study. A total of 80 Secondary School girls from St. Peter’s College, Olomore, Abeokuta, in Ogun Statef Nigeria, aged
between 10-17 years took part in the study. The subjects were not involved in competitive school sports. Stratified random sampling technique was used to select 40 pre-menarcheal and 40 post-menarcheal girls who were later randomly assigned to experimental and control groups. At the end of the Circuit training programme, 40 subjects completed the post measurements, so there were 10 subjects in each of four study groups (pre-menarcheal experimental, pre-menarcheal control, post-menarcheal control, post-menarcheal experimental, post-menarcheal control groups. The data collected were subjected to descriptive statistics of mean and standard deviation and inferential statistics and Analysis of Covariance (ANCOVA) (2-ways) using the difference score method to test the hypotheses for the study at 0.05 level of significance. Scheffe post-hoc analysis was used for further analysis to test whether there was any significant “f”. The results showed that in general, there was no significant difference in power pre- and post-menarcheal girls as a result of 12-weeks Circuit training programme. The findings also indicated that the main factor A (Status: pre- and post- menarcheal girls) and factor B (Study Conditions: Experimental and Control) were statistically significant. Subjects in the experimental groups had better power than those in the control group.

Chtara, et al (2005), examined the effects of the sequencing order of individualized intermittent endurance training combined with muscular strengthening on aerobic performance and capacity. For this purpose forty eight male sport students (mean (SD) aged at 21.4 (1.3) years) were divided into five homogeneous groups according to their
maximal aerobic speeds (v VO2 MAX). 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 v VO2 MAX; (3) a time to exhaustion test (tlim) at 100% v VO2 MAX; (4) a maximal cycling laboratory test to assess VO2 MAX. Results: 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 v VO2 MAX (p,0.01); 13.7%, 10.1%, 11.0%, and 6.4% for VO2MAX (ml/kg0.75 /min)(p,0.05) respectively. Similar significant results were observed for tlim and the second ventilator threshold (%V’O2MAX). Conclusions: 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.

*Takeshima et al*(2004) determined the physiological effects of a programmed accommodating circuit exercise(PACE) program consisting of aerobic exercise and hydraulic-resistance exercise (HRE) on fitness in older adults. Thirty-five volunteers were randomly divided into two
groups [PACE group (PG) of 8 men and 10 women, 68.3 (4.9) years, and non-exercise control group (CG) of 7 men and 10 women, 68.0 (3.4) years]. The PG participated in a 12-week, 3 days per week supervised program consisting of 10 min warm-up and 30 min of PACE (moderate intensity HRE and aerobic movements at 70% of peak heart rate) followed by 10 min cool-down exercise. PACE increased ( P<0.05) oxygen uptake ( \( V_{(l)O(2)} \)) at lactate threshold [PG, pre 0.79 (0.20) l min(-1), post 1.02 (0.22) l min(-1), 29%; CG, pre 0.87 (0.14) l min(-1), post 0.85 (0.15) l min(-1), -2%] and at peak \( V_{(l)O(2)} \) [PG, pre 1.36 (0.24) l min(-1), post 1.56 (0.28) l min(-1), 15%; CG, pre 1.32 (0.29) l min(-1), post 1.37 (0.37) l min(-1), 4%] in PG measured using an incremental cycle ergometer. Muscular strength evaluated by a HRE machine increased at low to high resistance dial settings for knee extension (9-52%), knee flexion (14-76%), back extension (18-92%) and flexion (50-70%), chest pull (6-28%) and press (3-17%), shoulder press (18-31%) and pull (26-85%), and leg press (21%). Body fat (sum of three skinfolds) decreased (16%), and high-density lipoprotein cholesterol (HDLC) increased (10.9 mg dl(-1)) for PG. There were no changes in any variables for CG. These results indicate that PACE training incorporating aerobic exercise and HRE elicits significant improvements in cardiorespiratory fitness, muscular strength, body composition, and HDLC for older adults. Therefore, PACE training is an effective well-rounded exercise program that can be utilized as a means to improve health-related components of fitness in older adults.
*Gotshalk et al (2004)* determined the level of cardiovascular stress elicited by continuous and prolonged circuit resistance training (CRT). Each of the 11 men who volunteered as a subject were tested to determine oxygen consumption and heart rate responses to a submaximal and maximal treadmill protocol and a CRT session consisting of 10 exercises and 10 repetitions at 40% of 1 repetition maximum (1RM) for each station with 4.6 circuits performed. The physiological stress of the CRT in this study was evident by the sustained heart rate of more than 70% of maximum for 16.6 minutes, with the last 12 minutes at more than 80%. Despite the large anaerobic component in CRT, VO2 was sustained at 50% or more of maximum for the final 12 minutes. Treadmill running, involving large muscle groups, increased VO2 more rapidly than CRT, where alternating larger and smaller muscle groups were used. In addition, at the same VO2 heart rate differed significantly between the 2 modes of activity. Heart rate in CRT was higher (at 165) than the heart rate of 150 found during treadmill running at the same 50% VO2. Such workouts may be used in a training cycle in classical linear periodization or in a nonlinear program day targeting local muscular endurance under intense cardio respiratory conditions, which may help individuals develop enhanced toleration of physiological environments where high cardiovascular demands and higher lactate concentrations were present.

*Williams and Cash (2001)* examined the extent to which participation in a 6-week circuit-weight training program produced changes in participants' body images relative to a matched control group. The weight trainers consisted of 39 college students (27 women
and 12 men). The control group of 39 individuals did not weight-train currently or within the past year. All participants were pre- and post tested on the Multidimensional Body Self-Relations Questionnaire, the Social Physique Anxiety Scale, and the Physical Self-Efficacy Scale. Weight trainers were also pre- and post tested on muscular strength and assessed on their motives for exercise. The program successfully increased upper- and lower-body strength. In contrast to the comparison group, weight trainers had a significantly improved evaluation of their appearance, greater body satisfaction, reduced social physique anxiety, and enhanced physical self-efficacy. Outcomes were unrelated to the extent of concurrent aerobic exercise and largely unrelated to exercise motives. Even a relatively brief weight training program can produce improvements in multiple aspects of body image. Further research should be done to investigate weight training as an adjunct to psychosocial treatments of body dissatisfaction.

Jacobs et al (2001), tested the safety and the effects of circuit resistance training (CRT) on peak upper extremity cardio respiratory endurance and muscle strength in chronic survivors of paraplegia due to spinal cord injury. For this purpose ten men with chronic neurologically complete paraplegia at the T5-L1 levels participated in the study. Subjects completed 12 wk of CRT, using a series of alternating isoinertial resistance exercises on a multi-station gym and high-speed, low-resistance arm ergometry. Peak arm
ergometry tests, upper extremity isoinertial strength testing, and testing of upper extremity isokinetic strength were all performed before and after training. None of the subjects suffered injury from exercise training. Significant increase were observed in peak oxygen consumption (29.7%, P < 0.01), time to fatigue (P < 0.01), and peak power output during arm testing (P < 0.05) is observed. Significant increases in isoinertial strength for the training maneuvers ranged from 11.9% to 30% (Ps < 0.01). Significant increases in isokinetic strength were experienced for shoulder joint internal rotation, extension, abduction, adduction, and horizontal adduction (Ps < 0.05). Chronic survivors of paraplegia safely improve their upper extremity cardio respiratory endurance and muscle strength when undergoing a short-term circuit resistance training program. Gains in fitness and strength exceeded those usually reported after either arm endurance exercise conditioning or strength training in this subject of population.

Kaikkonen et al (2000) investigated the effects of a 12-week low resistance circuit weight training (CWT) on cardiovascular and muscular fitness were studied in 90 healthy sedentary adults. The subjects were randomized into three equally fit groups: CWT, Endurance (END) and Control (CON) according to their maximal aerobic power (VO2max). Both training groups exercised for 12 weeks, 3 days a week in sessions of 40 min, with a heart rate (HR) level of 70-80% HRmax. The CWT group was trained with air resistance machines. Heart rate was controlled by setting the speed of movement. The END
group walked, jogged, cross-country skied or cycled. The net differences (between pre- and post training changes) between the CWT and CON groups was statistically significant for VO2max (2.45 ml x min(-1) x kg(-1), 95% CI 1.1; 3.8), for abdominal muscles (3.7 reps, CI 0.3; 7.1), for push-ups (1.1 reps, CI 0.2; 2.1), and for kneeling (2.25 reps, CI 0.01; 4.5). The net difference (between pre- and post training changes) in the END and CON groups was statistically significant for VO2max (2.75 ml(-1) x min(-1) x kg(-1), 95% CI 0.9; 4.6), and kneeling (3.0 reps, CI 0.7; 5.3). Low resistance CWT with moderately hard HR level has effects comparable to an equal amount of endurance training on the cardiovascular fitness of sedentary adults. The CWT model was also beneficial to muscular fitness. Based on the results, this type of exercise can be recommended for beginners because of its multilevel effects.

Dunston et al., (1998) assessed the effects of short time circuit weight training (CWT) on glycaemic control in NIDDM. Twenty-seven untrained, sedentary subjects (mean age, 51) with NIDDM participated in an eight week randomized and controlled study, involving eight CWT 3 days / week exercise (n = 15) or no formal exercise (control) (n = 12). All subjects performed regular self-blood glucose monitoring throughout. Fasting serum glucose and insulin were measured following a 12-h fast and during an oral glucose tolerance test (75 g) before and after 8 weeks. Twenty-one subjects completed the study (CWT, n = 11) (Control, n=10). Strength for all exercises improved
significantly after CWT. Pooled time-series analysis, using a random effects model, revealed an overall decrease in self-monitored glucose levels with CWT compared to controls. Significant reductions from baseline values were observed in both the glucose (-213 mmol·l⁻¹·h⁻¹, p < 0.05) and insulin (-6130 mmol·l⁻¹·h⁻¹, p < 0.05) area under the curve following CWT relative to controls. After adjustment for body mass changes, the change in self-monitored glucose levels and insulin area under the curve, but not glucose area under the curve, remained significant. Short-term CWT therefore might provide a practical exercise alternative in the lifestyle management of this condition.

Maiorana et al (1997) examined the effects of 10 weeks of CWT on muscular strength, peak oxygen consumption (peak VO₂), and myocardial oxygen demand (mVO₂) in men after coronary artery bypass surgery. Twenty-six, post-coronary bypass male subjects (mean 19 months after bypass), aged 60 +/- 8.5 years, were randomly allocated to 10 weeks of CWT at 40 to 60% of maximum voluntary contraction (n=12) or to a control group (n= 14). Muscular strength was assessed using a modified one repetition maximum technique. Peak VO₂ was recorded during symptom-limited treadmill exercise. Rate pressure product, as an indirect measure of mVO₂, was measured during isometric, isodynamic, and dynamic exercise. No ischemic symptoms nor electrocardiographic changes were recorded during testing or training. Strength increased by 18% (P < 0.005) in five out of seven exercises in the training group, but was unchanged in the control
Training did not improve peak VO$_2$. Rate pressure product during isometric and isodynamic exercise decreased from pre- to post-testing ($P < 0.05$) but was equivalent to that seen in the control group. Moderate intensity CWT is safe and can improve strength in selected low-risk patients after coronary artery bypass surgery. However, it does not significantly increase peak VO$_2$ nor reduce mVO$_2$ during isometric, isodynamic, and dynamic exercise.

*Pichon et al (1996)* compared metabolic cost and cost: work ratio to blood pressure and heart rate response between circuit and traditional weight training. Subjects (5 M, 3 F) completed one traditional and one circuit weight training workout. [Latin capital V with dot above]O$_2$ was measured during workout and recovery. Total work was calculated by summing the vertical work on the weights and limbs. Heart rate was continuously monitored. SBP and DBP were measured during the last 10 set of each leg exercise and once a minute during recovery. Cost: work ratios were significantly higher for traditional weight training ($p = 0.003$). However, due to the greater total workload, total metabolic cost was higher for circuit weight training ($p = 0.032$). Exercise and recovery rate-pressure product (RPP) were calculated. Exercise heart rate was significantly higher during circuit weight training. No differences were found in BP response. Exercising RPP was significantly higher during circuit weight training, indicating a higher workload on the heart. This might be an important consideration when recommending weight training programs for persons with cardiovascular complications.
Patricia et al (1994) determined the effects of a combined aerobic and circuit weight training program on maximal oxygen consumption, body composition, and muscular strength of college going women. Of the 33 who volunteered to participate, 17 were randomly assigned to the exercise program while the remaining 16 served as controls. The training involved a 45-min circuit of 30 activities including five 3-min aerobic exercises and 25 30-sec weight training or calisthenic exercises. The subjects exercised at 40 to 50% of their 1-RM for each weight station. Workloads for the aerobic stations were assigned based on the workload needed to elicit 75 to 85% of the maximal heart rate which reached during the \([\text{O}_2\text{ max}]\). Data were analyzed using repeated measures ANOVA with significance established at \(p < 0.05\). The exercise group had significant increases in \([\text{O}_2\text{ max}]\), upper body strength, and lower body strength, and significant decreases in skinfold sum and percent body fat. This indicated that an aerobic circuit weight training program was an effective way to improve cardiovascular fitness, body composition, and muscular strength in college going women.

Murphy et al (1992) compared the effects of standard set weight training (SWT) and circuit weight training (CWT) on excess post-exercise oxygen consumption (EPOC). The type and order of exercises were the same for both programs. The programs differed in three respects: a circuit approach as opposed to three sets of the same
exercise; the percent of maximum weight used was 80 percent in SWT and 50 percent CWT; and rest periods were shorter for CWT (30 seconds) than SWT (120 seconds). This longer rest period resulted in a longer SWT program (50 minutes) than the CWT program (19 minutes). Ten untrained college men performed both weight-training programs. Resting metabolic rate (RMR) was determined before each weight program, followed by a determination of EPOC. The magnitude and duration of EPOC produced by CWT were significantly (p < 0.01) greater than those produced by SWT. The EPOC produced by CWT was 20 minutes in duration with a net caloric cost estimated at 24.9 kilocalories, while that produced by SWT was 15 minutes in duration with an estimated net caloric cost of 13.5 kilocalories. The intensity of CWT (289 kilograms per minute) was also greater than that of SWT (106 kilograms per minute). It was concluded that the magnitude and duration of EPOC was greater for CWT in comparison to SWT and the EPOC produced by weight training is somewhat less than that found for aerobic exercise.

Katz and Wilson (1992), 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 effect on reducing resting systolic and diastolic blood pressure. The following changes occurred in the treatment group: (1) resting systolic blood pressure dropped significantly (from 113 to 99 mmHg) after training and (2) diastolic blood pressure dropped significantly from (70.9 to 62.0 mmHg) after training. However, there were no differences in these decreases between the exercise and control groups. The investigators concluded that low-intensity; resistive training should not increase blood pressure in white, healthy females, aged between 18 to 28 years.

*Jacobs et al (1987)*, demonstrated that strength training can improve +Gz acceleration tolerance. Based on these findings, the Canadian Forces have introduced a training program for aircrew of high performance aircraft. This report describes the changes in physical fitness components considered relevant to +Gz tolerance after 12 weeks of training with this program. Prior to beginning of the training, 45 military personnel were tested, but only 20 completed a minimum of 24 training sessions. The following variables were measured in these 20 subjects before and after training: maximal strength of several large muscle groups during isokinetic contractions, maximal aerobic power and an endurance fitness index, maximal anaerobic power, anthropometric characteristics, and maximal respiratory pressure generated during
exhalation. Training involved hydraulic resistance circuit training 2-4 times/week. The circuit consisted of 3 consecutive sets at each of 8 stations using Hydra-Gym equipment. The exercise: rest ratio was 20:40 s for the initial 4 training weeks and was then changed to 30:50. After training the changes in anthropometric measurements suggested that lean body mass was increased. Small, but significant, increases were also measured in muscle strength during bench press, biceps curls, squats, knee extension, and knee flexion. Neither maximal anaerobic power (i.e. muscular endurance) nor maximal expiratory pressure were changed after the training. Indices of endurance fitness were also increased in the present study. The relatively small increases in strength are probably due to the design of the exercise: rest ratio which resulted in improved strength and aerobic fitness.

*Harris and Holly (1987)*, investigated with Male subjects (10 experimental, 16 control) with borderline hypertension (140/90 to 160/95 mm Hg) participated in a circuit weight training program for 9 wk to assess its efficacy and safety. Resting blood pressure and heart rate were measured under standardized conditions prior to and following each session and at several locations in the circuit. Subjects were assessed at pre- and post-training. Upper and lower body strength increased 12.5 and 53% when assessed by one-repetition maximum lifts for bench press (57 to 64 kg) and leg press (134 to 205 kg), respectively. Total weight lifted per circuit increased 57% (4,374 to 6,866 kg). Lean body mass increased 2.2% (64.0 to 65.4 kg), skin fold
thicknesses decreased, and other measures of body composition remained unchanged. Cardiovascular endurance as assessed by arm ergometry maximal oxygen uptake increased 21.1% (1.9 to 2.3 1 X min-1), and by 7.8% as assessed by treadmill maximal oxygen uptake (40.9 to 44.1 ml X kg-1 X min-1). Resting heart rate and systolic blood pressure did not change. Diastolic blood pressure fell from 95.8 to 91.3 mm Hg. All changes were significant to at least P less than 0.05. Thus, circuit weight training can elicit marked improvements in muscular strength and modest improvements in body composition and cardio respiratory endurance. Circuit weight training does not exacerbate resting or exercise blood pressure and may have beneficial effects.