CHAPTER II
REVIEW OF RELATED LITERATURE
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The review of related literature is instrumental in the selection of topic, formulation of hypothesis and detective reasoning leading 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 field forms the foundation upon which all the future work will be built. If we fail to build upon the foundation of knowledge provided by review of literature, the researcher might miss some works already done on the same topic. The review of related literature is a crucial aspect of planning a study, the object of which is to justify the rationale behind a study.

2.1 STUDIES ON CRITICAL LITERATURE

Freitas, et al. (2016) investigated the acute effects of two different resistance circuit training protocols on basketball players' physical and technical performance and rating of perceived exertion (RPE). In a repeated-measures, crossover experimental design, 9 semi-professional basketball players performed a Power Circuit Training (PCT; 45% 1RM) and a High-Resistance Circuit Training (HRC; 6RM), on consecutive weeks. Vertical and horizontal jump performance, 3-points shooting accuracy, repeated-sprint ability (RSA), agility, and upper body power output were measured before and after training. The RPE was assessed 20 minutes after resistance training. One-way repeated-measures analysis of variance showed performance decrements in vertical jump height and peak power, horizontal jump distance, 3-points percentage, bench-press power output, RSA total and ideal
time, and agility T-Test at total time following HRC, but not PCT (p ≤ 0.05). The RPE was higher in HRC compared with PCT. The results of this study indicated that HRC was perceived as being harder and produced higher fatigue levels, which in turn lowered acute performance. However, low-to-moderate intensity loads did not negatively affect performance. Thus, completing a PCT session may be the most appropriate option before a practice or game as it avoids acute-resistance-training-induced performance decrements. However, if the objective of the basketball session is to develop or perfect technical skills during fatiguing conditions, HRC may be the more suitable option.

Schmidt, et al. (2016) conducted a study on the effect of high intensity circuit training on physical fitness. The purpose of the study was to examine the effect of a high intensity circuit training regimen, using only body weight as resistance, on physical fitness. Ninety-six recreationally active college aged subjects (53 female, 43 male) completed the study. Following baseline testing for height and weight, body composition, aerobic fitness, muscle strength and muscle endurance, subjects were randomly assigned to one of three groups: 7-minute circuit training (CT-7), 14-minute circuit training (CT-14), and a non-training control group (C). Subjects in the CT-7 group (females, N.=17; males, N.=15) were asked to complete a seven minute circuit training workout for eight weeks (three workouts per week). The CT-14 group (females, N.=15; males, N.=13) followed the same protocol as CT-7 through the first four weeks. For the second four weeks they increased exercise time to 14 minutes with the same 7 minute circuit performed twice consecutively. Subjects in group C (females, N.=21; males,
N.=15) maintained their normal activity levels throughout the course of the study. There were no significant differences between the groups for any variables tested prior to the exercise intervention. A repeated measures analysis of variance revealed statistically significant improvements in muscular endurance (push-ups) for both male and female subjects in the CT-7 and CT-14 groups. Males in the two exercising groups also showed improvement in muscular strength while aerobic capacity increased for females in the CT-14 group. These results suggest that short duration, high intensity circuit training may improve muscle endurance in moderately fit populations. Slight improvements that are gender specific may also be observed in muscle strength as well as aerobic fitness.

Vrachimis, et al. (2016) examined the effect of circuit training (CT) on resting heart rate variability (HRV) and other cardiovascular disease (CVD) risk factors such as blood lipids and blood glucose and on fitness components. Twenty-four healthy untrained adults (age 26.5 ± 5.1 years; height 1.67 ± 8.4 m; weight 66.8 ± 15.1 kg; 26.3% ± 5.2%; maximum oxygen uptake (VO₂ max) 48.5 ± 10.0 ml.kg⁻¹.min⁻¹) were assigned to either CT (n = 12) involving bodyweight exercises, or control (CON, n = 12) groups. Prior to the start and following the end of the six-week training period, time-, frequency-domain and nonlinear measures of resting HRV, arterial blood pressure, body composition, fasting blood lipids, lipoproteins and glucose, VO₂ max, upper body muscular endurance (UBME) and abdominal and hip flexor (AHFME), back strength (BS) and handgrip were assessed. None of the resting HRV measures (P > 0.05) were affected by the CT intervention. However, diastolic blood pressure decreased (P = 0.03), lean body weight (P = 0.03) increased,
VO₂ max (P = 0.03), UBME (P = 0.001), AHFME (P = 0.04), and BS (P = 0.03) were significantly higher following CT, whereas the other variables were not influenced by the CT. Six-week of CT involving bodyweight exercises has no significant impact on resting HRV. However, this type of training might decrease the risk for development of CVD by reducing arterial blood pressure and by improving body composition, aerobic capacity, muscular endurance and strength.

Yildirim, et al. (2016) investigated the potential benefits of Circuit resistance training (CRT) for upper extremity muscle strength, functional independence, and quality of life (QoL) in patients with paraplegia. Twenty-six patients with paraplegia who were participating in a conventional rehabilitation programme at a tertiary education and research hospital were enrolled in this study. The participants were randomly assigned to two groups. The exercise group participated in the CRT programme, which consisted of repetitive exercises for the upper extremities performed at fixed mechanical stations 5 sessions per week for 6 weeks, in addition to conventional rehabilitation. Participants in the control group received only conventional rehabilitation over the same period. The groups were compared with respect to QoL, as well as isokinetic muscle test outcomes in the upper extremities, using the Functional Independence Measure (FIM) and Borg's scale. Significant increases in scores on the physical component of the FIM, Borg's scale, and QoL in both the exercise and control groups were observed. Furthermore, the large majority of isokinetic values were significantly more improved in the exercise group compared to the control group. When post-treatment outcomes were compared between the groups, improvements in scores on the physical component
of the FIM and in most isokinetic values were significantly greater in the exercise group. The study showed that CRT has positive effects on muscle strength in the upper extremities and the physical disability components of the FIM when added to conventional rehabilitation programmes for paraplegic patients. However, no significant improvement in QoL scores were observed after adding CRT to a conventional treatment regime.

Sooriamurthy, (2014) conducted a study to investigate the effect of plyometric training; swiss ball training, circuit training on agility in volleyball players. For this study one hundred and twenty male junior volleyball players were chosen as subjects and their age ranged from 15 to 19 years. The subjects were selected randomly and they were divided into four groups namely Plyometric training group, Swiss ball training group, Circuit training group and Control group. Each group consists of thirty junior volleyball players. The criterion variable is agility and it was measured pre and post training. The 505 agility test was applied to assess the agility and the scores were analysed by analysis of covariance. The result discovered that there is significant improvement in all the experimental groups but the plyometric group has superior in agility than the other groups. This study concluded that regular participation of plyometric, swiss ball and circuit training can improve agility in junior volleyball players.

Elayaraja, and Nageswaran, (2013) attempted a study on effect of plyometric and circuit training on leg strength, horizontal and vertical explosive power. The following functional tests were used: leg strength – leg strength test, horizontal explosive power- (standing broad jump), Vertical explosive power
(sergeant jump test). To achieve the purpose of the study, 60 male school athletes were selected from the Government Higher Secondary School, Thuvarankurichy, Trichy District randomly. They were randomly assigned into Plyometric training group (n = 20), Circuit Training group (n = 20), and a control group (n= 20). Experimental groups trained three days a week for 12 weeks. The collected data were statistically analysed. Paired sample ‘t’ test was used to find out significant improvement and analysis of covariance (ANCOVA) was used to find out the significant difference among experimental and control groups and the Scheffe’s test was applied as post-hoc test to find out paired mean difference. In all the cases 0.05 level of confidence was fixed to test the hypothesis. This study concluded that the plyometric training was significantly effective in improving the Elastic leg strength, horizontal and Vertical explosive power than Circuit training group of school athletes.

Mayorga-Vega, et al. (2013) conducted a study to evaluate the effects of a circuit training programme along with a maintenance programme on muscular and cardiovascular endurance in children in a physical education setting. Seventy two children 10-12 years old from four different classes were randomly grouped into either an experimental group (n = 35) or a control group (n = 37) (two classes for each group). After an eight-week development programme carried out twice a week and a four-week detraining period, the experimental group performed a four-week maintenance programme once a week. The programme included one circuit of eight stations of 15/45 to 35/25 seconds of work/rest performed twice. Abdominal muscular endurance (sit-ups in 30 seconds test), upper-limbs muscular endurance
(bent arm hang test), and cardiovascular endurance (20-m endurance shuttle run test) were measured at the beginning and at the end of the development programme, and at the end of the maintenance programme. After the development programme, muscular and cardiovascular endurance increased significantly in the experimental group (p < 0.05). The gains obtained remained after the maintenance programme. The respective values did not change in the control group (p > 0.05). The results showed that the circuit training programme was effective to increase and maintain both muscular and cardiovascular endurance among school children.

Romero-Arenas, et al. (2013) conducted a study on effects of high-resistance circuit training in an elderly population. The aim of this study was to determine the efficacy of a programme of high-resistance circuit (HRC) training, and to compare the effects of HRC to traditional heavy strength (TS) training on strength, muscle size, body composition and measures of cardiovascular fitness in a healthy elderly population. Thirty-seven healthy men and women (61.6. ±. 5.3. years) were randomly assigned to HRC (n. =. 16), TS (n. =. 14), or a control group (CG, n. =. 7). Training consisted of weight lifting twice a week for 12 weeks. Before and after the training, isokinetic peak torque in the upper and lower body, and body composition (dual X-ray absorptiometry) were determined. In addition, cardiovascular parameters were evaluated during an incremental treadmill test. Both HRC and TS groups showed significant increases in isokinetic strength (p<. 0.001), and the increase was significantly greater in the experimental groups than in CG (p<. 0.03). There were significant increases in lean mass (HRC, p<. 0.001; TS, p=. 0.025) and bone mineral density (HRC, p=. 0.025; TS, p=. 0.018) in the experimental
groups. Only HRC showed a significant decrease in fat mass (p=. 0.011); this decrease was significantly greater in HRC than in CG (p=. 0.039). There were significant improvements in walking economy in the HRC group (p<. 0.049), although there were no statistical differences between groups. There were no changes in any variables in CG. Hence, HRC training was as effective as TS for improving isokinetic strength, bone mineral density and lean mass. Only HRC training elicited adaptations in the cardiovascular system and a decrease in fat mass.

Satya Paul Kumar, (2013) conducted a study on the comparative study on speed and muscular endurance in kho-kho players of circuit training among girls in Guntur district. The reason for the study was to figure out if there was any noteworthy impact of speed and husky perseverance of young ladies through chosen high-intensity exercise works out. 30 young lady's learner's ladies High School, Guntur were chosen at arbitrary as the subjects for this study. Two likened assemblies were defined of 15 each one blending them with the understanding one was named as aggregation X and were treated as the control bunch and the second assembly Y was subjected to the trial treatment. It was observed that there was a significant improvement in the speed and muscular endurance of experimental group through the circuit training programme. It was also found that there was no significant improvement in speed and muscular endurance of the control group which did not have the circuit training programme.

Bocalini, et al. (2012) investigated the impact of circuit-based exercise on the body composition in obese older women by focusing on physical exercise and body weight (BW) gain control in older people. Seventy older women (>60 years
old) voluntarily took part in the study. Participants were randomised into six different groups according to body mass index (BMI): appropriate weight (AW) control (AWC) and trained (AWT) groups, overweight (OW) control (OWC) and trained (OWT) groups, and obesity (O) control (OC) and trained (OT) groups. The exercise programme consisted of 50 minutes of exercise three times per week for 12 weeks. The exercises were alternated between upper and lower body using rest between sets for 40 seconds with intensity controlled by heart rate (70% of work). The contraction time established was 5 seconds to eccentric and concentric muscular action phase. The following anthropometric parameters were evaluated: height (m), body weight (BW, kg), body fat (BF, %), fat mass (FM, kg), lean mass (LM, kg), and BMI (kg/m(2)). In summary, circuit-based exercise is an effective method for promoting reduction in anthropometric parameters in obese older women.

Mukaimoto, and Ohno, (2012) conducted study to examine oxygen consumption (VO(2)) during and after a single bout of low-intensity resistance exercise with slow movement. Eleven healthy men performed the following three types of circuit resistance exercise on separate days: (1) low-intensity resistance exercise with slow movement: 50% of one-repetition maximum (1-RM) and 4 s each of lifting and lowering phases; (2) high-intensity resistance exercise with normal movement: 80% of 1-RM and 1 s each of lifting and lowering phases; and (3) low-intensity resistance exercise with normal movement: 50% of 1-RM and 1 s each of lifting and lowering phases. These three resistance exercise trials were performed for three sets in a circuit pattern with four exercises, and the participants performed each set until exhaustion. Oxygen consumption was monitored continuously during
exercise and for 180 min after exercise. The results of this study suggest that low-intensity resistance exercise with slow movement induces much greater energy expenditure than resistance exercise with normal movement of high or low intensity, and is followed by the same total excess post-exercise oxygen consumption for 180 min after exercise.

**Alcaraz, et al. (2011)** conducted a study on similarity in adaptations to high-resistance circuit vs. traditional strength training in resistance-trained men. To compare 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. 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 shorter training session duration.

**Duncan, et al. (2009)** conducted study on the effect of 6-week circuit-based training on body esteem and body mass index (BMI) in 68 British children (34
boys and 34 girls, aged 10-11 years, 16% overweight, 7% obese). The Body Esteem Scale for Children (BES-C) was administered to both the intervention group and control group, pre, post and 6 weeks post the intervention. BMI was directly assessed from height and body mass pre- and post-intervention. The results of this study revealed that, as compared to the control group, participation in 6-week circuit training significantly improved body esteem scores post-intervention. However, these scores were not sustained 6 weeks post-intervention. The improvement in body esteem scores from pre- to post-intervention was greater for girls as compared to boys. Additionally, BMI decreased significantly in the intervention group compared to the control group.

Taşkin, (2009) conducted a study on effect of circuit training on the sprint-agility and anaerobic endurance. The purpose of this study was to determine the effect of circuit training directed toward motion and action velocity over the sprint-agility and anaerobic endurance. A total of 32 healthy male physical education students with a mean age of 23.92 +/- 1.51 years were randomly allocated into a circuit training group (CTG; n = 16) and control group (CG; n = 16). A circuit training consisting of 8 stations was applied to the subjects 3 days a week for 10 weeks. Circuit training programme 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 training, there was a significant (p < 0.05) difference in sprint-agility between pre- and post-
testing for the CTG (pre-test = 14.76 +/- 0.48 seconds, post-test = 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 (pre-test = 31.53 +/- 0.48 seconds, post-test = 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.

Alcaraz, et al. (2008) compared physical performance parameters and cardiovascular load during heavy-resistance circuit (HRC) training to the responses during a traditional, passive rest strength training set (TS). Ten healthy subjects (age, 26 +/- 1.6 years; weight, 80.2 +/- 8.78 kg) with strength training experience volunteered for the study. Testing was performed once weekly for 3 weeks. On day 1, subjects were familiarised with the test and training exercises. On the subsequent 2 test days, subjects performed 1 of 2 strength training programmes: HRC (5 sets x (bench press + leg extensions + ankle extensions); 35-second interset rest; 6 repetition maximum [6RM] loads) or TS (5 sets x bench press; 3-minute interset rest, 6RM loads). The data confirm that the maximum and average bar velocity and power and the number of repetitions performed of the bench press in the 2 conditions was the same; however, the average heart rate was significantly greater in the HRC compared to the TS condition (HRC = 129 +/- 15.6 beats x min(-1), approximately 71% maximum heart rate (HRmax), TS = 113 +/- 13.1 beats x min(-1), approximately 62% HRmax; P < 0.05). Thus, HRC sets are quantitatively similar to traditional strength training sets, but the cardiovascular load is substantially greater. HRC may be an effective training strategy for the promotion of both strength and cardiovascular adaptations.
Chtara, et al. (2008) conducted a study on effect of concurrent endurance and circuit resistance training sequence on muscular strength and power development. Forty-eight physical education students (ages, 21.4 ±1.3 years) were assigned to 1 of 5 groups: no training controls (C, n = 9), endurance training (E, n = 10), circuit training (S, n = 9), endurance before circuit training in the same session, (E+S, n=10), and circuit before endurance training in the same session (S+E, n = 10). Subjects performed 2 sessions per week for 12 weeks. Resistance-type circuit training targeted strength endurance (weeks 1–6) and explosive strength and power (weeks 7–12). Endurance training sessions included 5 repetitions run at the velocity associated with VO$_2$ max (VO$_2$ max) for a duration equal to 50% of the time to exhaustion at VO$_2$ max; recovery was for an equal period at 60% VO$_2$ max. 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 intra-session 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 intra-session sequencing.
Adeniji, (2007) conducted a study to examine the comparative effects of circuit training programme on speed and power of 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 State of Nigeria, ages 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 training programme, 40 subjects completed the post training measurements, so there were 10 subjects in each of the four study groups (pre-menarcheal experimental, pre-menarcheal control, post-menarcheal control, post-menarcheal experimental, post-menarcheal control groups). The Implications of this study are that exercise training such as the circuit used in this study can make observable differences in speed and power of adolescents. Effective exercise training programmes should therefore be considered as an integral and inevitable aspect of school curriculum.

Braun, et al. (2005) evaluated the effects of circuit training (CT) and treadmill exercise performed at matched rates of oxygen consumption and exercise duration on elevated post-exercise oxygen consumption (EPOC) in untrained women, while controlling for the menstrual cycle. Eight, untrained females (31.3 +/- 9.1 years; 2.04 +/- 0.26 l min(-1) estimated VO2max; BMI=24.6+/-3.9 kg/m2) volunteered to participate in the study. Testing was performed during the early follicular phase for each subject to minimise hormonal variability between tests. Subjects performed two exercise sessions approximately 28 days apart. Resting,
supine energy expenditure was measured for 30 min preceding exercise and for 1 h after completion of exercise. Respiratory gas exchange data were collected continuously during rest and exercise periods via indirect calorimetry. CT consisted of three sets of eight common resistance exercises. When exercise VO$_2$ and exercise duration were matched, CT was associated with a greater metabolic disturbance and cost during the early phases of EPOC.

Gotshalk, et al. (2004) conducted study to determine 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, VO$_2$ was sustained at 50% or more of maximum for the final 12 minutes. Treadmill running, involving large muscle groups, increased VO$_2$ more rapidly than CRT, where alternating larger and smaller muscle groups were used. In addition, at the same VO$_2$ 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% VO$_2$. Such workouts may be used in a training cycle in classical linear periodisation or in a nonlinear programme day targeting local muscular endurance under intense cardiorespiratory conditions, which may help individuals develop enhanced
toleration of physiological environments where high cardiovascular demands and higher lactate concentrations are present.

Marx, (2001) attempted a study to determine the long-term training adaptations associated with low-volume circuit-type versus periodised high-volume resistance training programmes in women. 34 healthy, untrained women were randomly placed into one of the following groups: low-volume, single-set circuit (SSC; N = 12); periodised high-volume multiple-set (MS; N = 12); or non-exercising control (CON) group (N = 10). The SSC group performed one set of 8-12 repetitions to muscular failure 3 d x wk(-1). The MS group performed two to four sets of 3-15 repetitions with periodised volume and intensity 4 d x wk(-1). Muscular strength, power, speed, endurance, anthropometry, and resting hormonal concentrations were determined pre-training (T1), after 12 wk (T2), and after 24 wk of training (T3). 1-RM bench press and leg press, and upper and lower body local muscular endurance increased significantly (P ≤ 0.05) at T2 for both groups, but only MS showed a significant increase at T3. Muscular power and speed increased significantly at T2 and T3 only for MS. Increases in testosterone were observed for both groups at T2 but only MS showed a significant increase at T3. Cortisol decreased from T1 to T2 and from T2 to T3 in MS. Insulin-like growth factor-1 increased significantly at T3 for SSC and at T2 and T3 for MS. No changes were observed for growth hormone in any of the training groups. Significant improvements in muscular performance may be attained with either a low-volume single-set programme or a high-volume, periodised multiple-set programme during the first 12 wk of training in untrained women. However, dramatically different
training adaptations are associated with specific domains of training programme design which contrast in speed of movement, exercise choices and use of variation (periodisation) in the intensity and volume of exercise.

**Halton, et al. (1999)** conducted study to determine the effect of rest-interval duration upon the magnitude of 1 h of excess post exercise oxygen consumption (EPOC). Seven healthy men completed two randomised circuit weight training sessions using 20-s and 60-s rest intervals (20 RI, 60 RI). Sessions included two circuits of eight upper and lower body resistive exercises in which 20 repetitions were performed at 75% of a previously determined 20 repetition maximum. Data demonstrate that shortening the rest interval duration will increase the magnitude of 1 h EPOC from CWT; however, the exercise + recovery caloric costs from CWT are slightly greater for a longer rest interval duration protocol. These data suggest that total caloric cost be taken into account for CWT.

**Pichon, (1996)** conducted study to compare 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. VO2 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. Exercising RPP was significantly higher during circuit weight training, indicating a higher workload on the heart. This may be an important consideration when recommending weight training programmes for persons with cardiovascular complications.
Mosher, (1994) conducted study to determine the effects of a combined aerobic and circuit weight training programme on maximal oxygen consumption, body composition, and muscular strength of college-age women. Of the 33 who volunteered to participate, 17 were randomly assigned to the exercise programme 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 callisthenic 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 reached during the VO2 max test. Result of the study indicated that an aerobic circuit weight training programme is an effective way to improve cardiovascular fitness, body composition, and muscular strength in college-age women.

Murphy, et al. (1992) conducted study to compare 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 programmes. The programmes 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 programme (50 minutes) than the CWT programme (19 minutes). Ten untrained college men performed both weight-training programmes. Resting metabolic rate (RMR) was determined before each weight programme, followed by a determination of EPOC. It was concluded that the magnitude and duration of EPOC is greater for
CWT in comparison to SWT and the EPOC produced by weight training is somewhat less than that found for aerobic exercise.

Haennel, et al. (1989) conducted study on effect of hydraulic circuit training (HCT) on cardiovascular (CV) function. It was assessed in 32 healthy middle-aged males (X age = 42.2 +/- 2.1 yr). Maximal aerobic power (VO$_2$ max), with simultaneous measurement of stroke volume (SV) and cardiac output (CO), by impedance cardiography, was assessed pre- and post-training. Subjects were randomly assigned to a non-exercising control group, a cycle training group (cycle), or one of the two HCT groups. Training groups participated in a 9 wk programme, 3 d.wk-1. Subjects assigned to HCT exercised on a 9 station circuit, completing 3 circuits.d-1. Each circuit consisted of three 20 s work intervals at each station with a 1:1 work: rest ratio. One HCT group (HCT max) completed the maximal repetitions possible (RM) during each work interval. The other HCT group (HCT sub) exercised at 70-85% of RM. The findings suggested that both maximal and submaximal HCT programmes can elicit improvements in cardiovascular fitness.

Petersen, et al. (1988) investigated the influence of high-velocity resistance circuit training on maximal aerobic power. Twenty-seven trained males participated either as training (N = 16) or control (N = 11) subjects. The training group exercised for two 20 sec sets at each of six stations of hydraulic, variable resistance apparatus over two or three circuits maintaining an exercise: relief ratio of 1:2 during each circuit. Subjects trained four times weekly over 5 weeks. The resistance at each station was adjusted as necessary to maintain consistent angular limb velocities of
approximately 3.2 rad/sec. The findings suggested that the hydraulic circuit resistance programme described will elicit a metabolic intensity sufficient to improve aerobic power, even in previously trained subjects.

**Gettman, et al. (1982)** conducted study to compare the physiologic effects of a programme of combined running and weight training (RUN-CWT) with a programme of circuit weight training (CWT). Thirty-six females (X age = 35.7 yr) and 41 males (X age = 36.1 yr) were randomly assigned to RUN-CWT, CWT, and control groups. The training groups participated in 12-wk programmes, 3 d .wk-1. Three circuits of 10 weight-training exercises were completed with 12-15 repetitions performed in 30 s at 40% of one-repetition maximum at each station. The 30-min RUN-CWT programme included 30 s of running on an indoor track following each CWT station, whereas the 22.5 min CWT programme included a 15-s rest period between stations. Statistically, one training programme was not shown to be superior to the other; thus, both programmes of RUN-CWT and CWT were effective in improving measures of physical fitness.

**Gettman, et al. (1979)** attempted a study on physiologic effects on adult men of circuit strength training and jogging. Their research indicates that the jogging programme elicited significantly greater changes in treadmill performance time and VO\(_2\) max. Further reductions were found in total skinfolds and waist girth during the jogging programme. Leg strength was maintained during jogging but upper body strength was reduced significantly. Physiologic levels were maintained during the final 8 weeks and showed no differences between the circuit strength training and jogging groups.
2.2 STUDIES ON ALLIED LITERATURE

Jones, et al. (2017) examined the differences in performance and heart rate responses between a high heat outdoor condition (34.0°C, 64.1% humidity) and a temperate indoor condition (22.0°C, 50.0% humidity) during the 30-15 intermittent fitness test (30-15IFT). Eight highly trained Rugby Union players (28.1 ± 1.5 years, 181.4 ± 8.8 cm, 88.4 ± 13.3kg) completed the 30-15IFT in two different temperature conditions. Dependant variables recorded and analysed included; final running speed of the 30-15IFT, heart rate (HR) at rest (HR rest), maximum HR (Max HR), HR recovery (HRR), average HR (HR ave) and sub-maximal HR corresponding to 25%, 50% and 75% of final test speed (HR 25%, HR 50% and HR 75%) and HR at 13 km·h (HR 13 km·h). The results of this study highlight the influence of temperature on 30-15IFT performance and cardiac responses. It is recommended that prescription of training based on 30-15IFT results reflects the temperature that the training will be performed in and that practitioners acknowledge that a meaningful change in assessment results can be the result of seasonal temperature change rather than training induced change.

Rivas, et al. (2017) investigated if leg compressions would alter cardiorespiratory and perceived exertion measures during rest, submaximal and maximal exercise in endurance-trained runners. Thirteen young, endurance trained runners (10 males, 20.9±3y, 58.9±5.7mlkgmin⁻¹) completed a randomised design, leg compressions and non-compression control condition. The incremental graded exercise test consisted of baseline rest and submaximal intensities at 23%, 70%, 75%, 85% and then a progressive increase to 100% VO₂ max. Running economy
(RE), rating of perceived exertion (RPE), breathing rate (BR), heart rate (HR), ventilation (VE), blood lactate, VO$_2$max and ventilatory efficiency (VE/VO$_2$) were the primary outcome variables. These data suggested that leg compressions do not alter RE, RPE, BR, HR, or VO$_2$, during exercise. However, compressions may be beneficial for submaximal and maximal ventilatory efficiency while improving lactate clearance at VO$_2$ max and during recovery in trained runners.

Tocci, et al. (2017) investigated whether high levels of strenuous physical activity outside of organised sports are associated with better functional test performance. Youth athletes (n = 445, mean = 14.2 ± 2.5 years) reported their frequency of strenuous physical activity outside of organised sports. The functional performance tests: vertical jump height, pro agility test time, estimated maximal oxygen uptake (VO$_2$ max), front plank time and postural stability were measured and compared between groups. Youth athletes who engaged in strenuous physical activity outside of organised sports five or more times a week performed best on functional performance tests.

Janura, et al. (2016) conducted a study on evaluation of explosive power performance in ski jumpers and nordic combined competitive athletes: a 19-year study. Between 1992 and 2010, a total of 334 males participated in this study that assessed the differences and relationships between anthropometric variables and lower limb muscle strength in young and adult ski jumpers (n = 207) and Nordic combined (NC, n = 127) athletes. All athletes completed a maximal vertical jump from an in-run position and a maximal relative isometric force (MRIF) of the knee extensor measurement in a laboratory setting. The body mass index (BMI) in young
competitors was lower than in adult groups (NC: \( p < 0.001 \); ski jumping [SJ]: \( p < 0.001 \)). Similarly, the MRIF in both limbs was lower for both disciplines in the groups of young competitors. The vertical jump height (VJH) was lower for young competitors than for adults (NC: \( p \leq 0.05 \); SJ: \( p < 0.001 \)). When comparing SJ and NC athletes, BMI was lower in SJ athletes. In addition, the adult SJ competitors exhibited greater values of bilateral MRIF (\( p \leq 0.05 \)) and VJH (\( p < 0.01 \)). There was a strong positive correlation in MRIF between the left and right lower limbs (\( p < 0.001 \)) for all groups of SJ and NC athletes; therefore, it was determined to be sufficient to measure the MRIF on a single limb. Application of the new training methods (e.g., less emphasis on maximum resistance exercises) resulted in improved explosive power in ski jumpers even at lower-body weights. These changes are in accordance with the change in ski jump techniques.

**Methenitis, et al. (2016)** investigated the relationship between vastus lateralis MFCV and countermovement jumping performance, the rate of force development and maximum isometric force. Fifteen moderately-trained young females performed countermovement jumps as well as an isometric leg press test in order to determine the rate of force development and maximum isometric force. Vastus lateralis MFCV was measured with intramuscular micro-electrodes at rest on a different occasion. Result of the study suggested that muscle fibre conduction velocity is better linked with the rate of force development than with isometric force, perhaps because conduction velocity is higher in the larger and fastest muscle fibres which are recognised to contribute to explosive actions.
**Park, and Lee, (2015)** attempted a study on the effect of circuit exercise training and detraining, which is defined by termination of training without additional physical activities, in type 2 diabetic patients. Elderly with type 2 diabetes were divided into a group that exercised for 1 h three times a week for 12 weeks, followed by detraining for 8 weeks, or into a control group. Muscular strength, endurance, flexibility, agility, balance, body mass index (BMI), glycosylated haemoglobin (HbA1c), and blood lipid profile were measured. Of the 98 diabetic participants who joined this study, 37 patients completed the programme (exercise group = 24, control group = 13). After training, muscular strength, flexibility, balance, agility, and endurance in the training group were significantly higher than at baseline and compared to the control group. HbA1c levels decreased in the training group. There was no significant improvement in BMI and blood lipid profile in either group. Flexibility and agility in the training group declined significantly after detraining. In spite of this decline, flexibility and agility were significantly higher compared to the baseline and to the control group. In type 2 diabetic patients, circuit training had a beneficial effect on the indices of physical function and glucose metabolism. Training resulted in good improvement; and during detraining, the effect of exercise training was maintained except in some parameters.

**Rumpf, et al. (2015)** conducted a study on the effect of different sprint training methods on sprint performance over various distances. The purpose of the study was to perform a brief review as to the effect of specific (free sprinting; resisted sprinting by sleds, bands, or incline running; assisted sprinting with a towing device or a downhill slope), nonspecific (resistance and plyometric training),
and combined (a combination of specific and nonspecific) training methods on different sprint distances (0-10, 0-20, 0-30, and 31+ m). A total of 48 studies fulfilled the inclusion criteria, resulting in 1,485 subjects from a range of athletic backgrounds. The training effects associated with specific sprint training were classified as moderate (effect size [ES] = -1.00; %change = -3.23). The largest training effects for the effect of specific sprint training were observed for the 31+ m distance. For non-specific training, the greatest training effects were observed for the 31+ m distance. The greatest training effects for the combined training were observed for the 0-10 m distance. It was concluded that the most beneficial method over the investigated distances was specific sprint training method. However, for the benefit of speed and athletic performance the non-specific training methods (e.g., strength and power training) was also recommended.

**Tarik Ozmen, et al. (2014)** investigated the effect of explosive strength training on speed and agility performance in wheelchair basketball players. Ten male wheelchair basketball players (M_{age}=31±4 yrs) were divided into two groups [i.e. explosive strength training (ES); control (CN)] based on International Wheelchair Basketball Federation (IWBF) classification scores. The ES group underwent 6-weeks of training, twice weekly, at 50% 1RM, 10-12 repetitions and 3-4 sets in addition to routine training. Effects of training were measured by the 20 m sprint test and Illinois agility test. The ES group, showed significantly higher increases in speed and agility performance (p ≤ .05). A short-duration (i.e. 6-week) explosive strength training programme in wheelchair basketball athletes results in significant improvements in sprint and agility performance.
Buchan, et al. (2013) examined whether high intensity interval training (HIT) improves the CVD risk profile of secondary school aged adolescents. Their secondary objective was to identify the prevalence of CVD risk factors and examine factors associated with these in adolescents aged 15-18 years. A south Lanarkshire school of low socioeconomic status (SES) was selected to participated in the study intervention. Participants from secondary 5(15-17 years) and 6(156-18 years) was be recruited for this study. Participants from secondary 6 was randomly assigned to group A (HIT) or group B (moderate – vigorous) and performed each protocol three times weekly. The secondary 5 participants acted as the control group. Data collection took place during the physical education (PE) lessons and on school premises and included: anthropometrical variable (height, weight, waist and hip circumference, skin fold thickness at two sites), physiological responses (blood pressure, aerobic fitness, heart rate (HR) response, vertical jump performance, 10-meter (m) sprint and 505- agility test), diet (self-reported seven – day food diary), physical activity (physical activity questionnaire for adolescents (PAQ-A) and blood test (fasting glucose, insulin, total cholesterol (TC), high- density Lipoproteine (HDL), high-sensitivity C-reactive protein (hs-CRP), Fibrinogwen (Fg), interleukine-6 (IL-6), adaiponenctin (high molecular weight), triglyceride and plasminogen activator inhibitor -1 (PAI). An environment audit of the participants was also be measured. Finally, all exercise sessions was video recorded and rate of perceived exertion (RPE) and mood states was also taken after each exercise session. Their study demonstrated a time efficient means of reducing CVD risk factors in adolescents.
Lockie, et al. (2012) conducted a study on field sport athletes. They studied the effects of different speed training protocols on sprint acceleration kinematics and muscle strength and power. To improve field sport acceleration (e.g., free sprinting, weights, plyometrics, resisted sprinting), a variety of resistance training interventions are used but there is no clarity about the effects these protocols have on acceleration performance and components of sprint technique. Four common protocols of field sport athletes were assessed for determining the changes in acceleration kinematics, power, and strength namely free sprint training [FST], weight training [WT], plyometric training [PT], and resisted sprint training [RST]. A total of thirty-five men were selected and divided into 4 groups (FST: n = 9; WT: n = 8; PT: n = 9; RST: n = 9) matched for 10-m velocity. Training schedule involved two 60-minute sessions per week for 6 weeks. After the training, paired-sample t-tests identified significant (p ≤ 0.05) within-group changes. There was 9-10% increase in the 0- to 5-m and 0- to 10-m velocity in all the groups. There was approximately 10% increase in the 5- to 10-m velocity in both WT and PT groups. Step length increased in all the groups for all distance intervals. There was a decrease in the 0- to 5-m flight time and step frequency in all intervals and increase in the 0- to 5-m and 0- to 10-m contact time for the FST group. Power and strength adaptations were protocol specific. The horizontal power of the FST group improved as measured by a 5-bound test. The reactive strength index improved in the FST, PT, and RST groups derived from a 40-cm drop jump, which indicated enhanced muscle stretch-shortening capacity during rebound from impacts. There was approximately 15% increase in the absolute and relative strength in the WT group which was measured by a 3-repetition maximum squat. In this study step length was the major
limiting sprint performance factor for the athletes. Each training protocol can be
effective in improving acceleration when correctly administered. Field sport athletes
should develop specific horizontal and reactive power to increase step length and
improve acceleration.

Saez de Villarreal, et al. (2012) conducted a study on the effects of
plyometric training on sprint performance: a meta-analysis. The purpose of this
meta-analysis was to attempt to gain a clear picture of the magnitude of sprint
performance improvements expected after chronic plyometric training (PT) and to
identify specific factors that influence the treatment effects. Studies employing a PT
intervention and containing data necessary to calculate effect size (ES) were
included in the analysis. A total of 26 studies with a total of 56 ES met the inclusion
criterion. Analysis of ES demonstrated that the strategies that seem to maximise the
probability of obtaining significantly (p < 0.05) greater improvement in sprint
performance included training volume for <10 weeks; a minimum of 15 sessions;
and high-intensity programmes with >80 combined jumps per session. To optimise
sprint enhancement, the combination of different types of plyometrics and the use of
training programmes that incorporate greater horizontal acceleration (i.e., sprint-
specific plyometric exercises, jumps with horizontal displacement) would be
recommended, rather than using only one form of jump training (p < 0.05). No extra
benefits were found to be gained from doing plyometrics with added weight. The
loading parameters identified in this analysis should be considered by the
professional sprinters and specialised trainers with regard to the most appropriate
dose-response trends PT to optimised sprint performance gains.
Baljinder Singh, et al. (2011) conducted a study on young basketball players to find out the effects of a short term plyometric training programme on agility. A group of Thirty (N=30) male basketball players aged 18 – 24 years, who participated in intercollegiate basketball competitions organised by the Department of Sports, Guru Nanak Dev University, volunteered to participate in this study. Their mean height, weight, and age were 1.87±0.06m, 75.5± 5.2kg, 22.5± 0.4 years. All subjects, after having been informed about the objective and protocol of the study, gave their written consents and the study was approved by the local Committee of Ethics. The subjects were randomly assigned into two groups: experimental (E; n = 15) and control (C; n = 15). Group E was subjected to a 6-week training, 25 min a day. Student’s t-test for independent data was used to assess the between-group differences and for dependent data to assess the Post-Pre differences. Level of $p \leq 0.05$ was considered significant. It was concluded that the use of plyometrics training programme not only helped to break the monotony of training, but they can also improve the strength of basketball players.

Johnson, et al. (2011) conducted a study on a systematic review: plyometric training programmes for young children. The purpose of this systematic review was to evaluate the efficacy and safety of plyometric training for improving motor performance in young children; to determine if this type of training could be used to improve the strength, running speed, agility, and jumping ability of children with low motor competence; and to examine the extent and quality of the current research literature. Primary research articles were selected if they (a) described the outcomes of a plyometric exercise intervention; (b) included measures of strength, balance,
running speed, jumping ability, or agility; (c) included prepubertal children 5-14 years of age; and (d) used a randomised control trial or quasiexperimental design. Seven articles met the inclusion criteria for the final review. The 7 studies were judged to be of low quality (values of 4-6). Plyometric training had a large effect on improving the ability to run and jump. Preliminary evidence suggests plyometric training also had a large effect on increasing kicking distance, balance, and agility. The current evidence suggests that a twice a week programme for 8-10 weeks beginning at 50-60 jumps a session and increasing exercise load weekly results in the largest changes in running and jumping performance. An alternative programme for children who do not have the capability or tolerance for a twice a week programme would be a low-intensity programme for a longer duration. The research suggests that plyometric training is safe for children when parents provide consent, children agree to participate, and safety guidelines are built into the intervention.

**Andersen, et al. (2010)** examined the cardiac effects of football training and running for inactive pre-menopausal women by standard echocardiography and tissue Doppler Imaging. Thirty-seven subjects were randomised to two training groups (football: FG: n=19 : n=`18) training 1 h with equal average heart rates twice a week for 16 weeks and compared with a matched inactive control group (CG :n=10). In conclusion, 16 weeks of football and running exercise training induced significant change of cardiac dimension and had favourable effect on both left ventricular systolic and diastolic function. These training – induced cardiac adaptation appeared to be more consistent after football training compared with running.
Buchheit, et al. (2010) conducted a study on young elite soccer players. They compared the effects of explosive strength (ExpS) vs. repeated shuttle sprint (RS) training on repeated sprint ability (RSA). Fifteen elite male adolescents (14.5 ± 0.5 years) were selected to undergo training programme in addition to their training programmes in soccer. The training schedule was RS (n = 7) or ExpS (n = 8) training once in a week. The total duration of the training programme was 10 weeks. The RS training programme consisted of 2-3 sets of 5-6 × 15- to 20-m repeated shuttle sprints interspersed with 14 seconds of passive or 23 seconds of active recovery (≈2 m·s⁻¹). The ExpS training consisted of 4-6 series of 4-6 exercises (e.g., maximal unilateral countermovement jumps (CMJs), calf and squat plyometric jumps, and short sprints). Assessment of performance was done by 10 and 30 m (10 and 30 m) sprint times, best (RSAbest) and mean (RSAmean) times on a repeated shuttle sprint ability test, a CMJ, and a hopping (Hop) test before and after training. All performances were significantly improved in both groups (all p's < 0.05) except for 10 m (p = 0.22) after training. Relative changes were similar for both groups (p = 0.45) in 30 m (-2.1 ± 2.0%). When compared to ExpS, RS training induced greater improvement in RSAbest (-2.90 ± 2.1 vs. -0.08 ± 3.3%, p = 0.04) and tended to enhance RSAmean more (-2.61 ± 2.8 vs. -0.75 ± 2.5%, p = 0.10, effect size [ES] = 0.70). When compared to RS, ExpS induced greater improvements in CMJ (14.8 ± 7.7 vs. 6.8 ± 3.7%, p = 0.02) and Hop height (27.5 ± 19.2 vs. 13.5 ± 13.2%, p = 0.08, ES = 0.9). Improvement was observed in the repeated shuttle sprint test only after RS training, whereas increase in CMJ height was observed after ExpS training. As it was found that RS and ExpS were equally efficient at enhancing
maximal sprinting speed, RS training-induced improvements in RSA were likely to be more related to progress in the ability to change direction.

**Karve, and Tiwari, (2010)** assessed the effect of training on different running surfaces on the calf and thigh circumference of athletes. 120 PU college athletes from different colleges of Gulbarga District were selected as subjects by random sampling method and divided into four equal groups of 30 athletes in each group: Ex. Group I running training on sand, Ex. Group II running training on red mud track, Group III running training on cinder track and Group IV served as control group. Before the training on different running surfaces, the performances of 12 min run and walk test and vertical jump and also calf and thigh circumference of each athlete is measured as pre-test results. Eight weeks training programme on different surfaces is conducted to all the three groups simultaneously and no training was given to control group. After the training the calf and thigh circumference of each athlete is measured as post-test results, further vertical jump test is administered and also Cooper's 12 min run and walk test is conducted on the cinder track. There is a significant effect of running training on different surfaces on the performances of three groups. There is a significant effect of running training on different surfaces on the performance of Group III (running training on sand) as compared to other two groups. Calf and thigh circumference increased significantly in sand runners. Both treatment groups showed a similar significant increase in vertical jump. The 12-min run/walk was significantly increased in sand runners.

**Larose, et al. (2010)** evaluated the effects of aerobic exercise training (A), resistance training (A+R) and a sedentary control group (c) on cardio respiratory
fitness and muscular strength in individual with T2DM. 251 participants in the Diabetes Aerobic and Resistance Exercise (DARE) trial were randomly allocated to A, R, A+R or C. Peak oxygen consumption (VO₂ peak), workload and treadmill time were determined following maximal exercise testing at 0 and 6 months. Combined training did not provide additional benefits nor did it mitigate improvement in fitness in younger subjects compared to aerobic and resistance training alone.

Meylan, et al. (2009) conducted a study on effects of in-season plyometric training within soccer practice on explosive actions of young players. Fourteen children (13.3 +/- 0.6 years) were selected as the training group (TG) and 11 children (13.1 +/- 0.6 years) were defined as the control group (CG). All children were playing in the same league and trained twice per week for 90 minutes with the same soccer drills. The TG followed an 8-week plyometric programme (i.e., jumping, hurdling, bouncing, skipping, and footwork) implemented as a substitute for some soccer drills to obtain the same session duration as CG. At baseline and after training, explosive actions were assessed with the following 6 tests: 10-meter sprint, agility test, 3 vertical jump tests (squat jump [SJ], countermovement jump [CMJ], contact test [CT] and multiple 5 bounds test [MB5]). Plyometric training was associated with significant decreases in 10-m sprint time (-2.1%) and agility test time (-9.6%) and significant increases in jump height for the CMJ (+7.9%) and CT (+10.9%). No significant changes in explosive actions after the 8-week period were recorded for the CG. The current study demonstrated that a plyometric programme within regular soccer practice improved explosive actions of young players.
compared to conventional soccer training only. Therefore, the short-term plyometric programme had a beneficial impact on explosive actions, such as sprinting, change of direction, and jumping, which are important determinants of match-winning actions in soccer performance.

Peeling, et al. (2009) assessed the effect of training intensity and ground surface type on haemolysis, inflammation and hepcidin activity during running. Ten highly trained male endurance athletes completed a grade exercise test two continuous 10 km run on a grass (GRASS) and bitumen road surface (ROAD) at 75%-80% peak VO$_2$ running velocity and a 10x1 km interval running session (INT) at 90% - 95% of the peak VO$_2$ running velocity venous blood and urine sample were collected before, immediately after and at 3 and 24 h after exercise, serum samples were analysed for circulating level of IL-6, free haemoglobin (Hb) haptoglobin (Hp), iron and ferritin, Urine samples were analysed for changes in hepcidin expression. Serum iron and ferritin were significantly increased after exercise in all three condition (P< 0.05) but were not different between trails greater running intensities incur more inflammation and haemolysis, but these variables were not affected by the surface type trained upon.

Thomas, et al. (2009) conducted a study on youth soccer players. They compared the effects of two types of plyometric training techniques on power and agility. Twelve males from a semiprofessional football club's academy (age = 17.3 +/- 0.4 years, stature = 177.9 +/- 5.1 cm, mass = 68.7 +/- 5.6 kg) were randomly assigned to 6 weeks of depth jump (DJ) or countermovement jump (CMJ) training twice weekly. Participants in the DJ group performed drop jumps with instructions
to minimise ground-contact time while maximising height. Participants in the CMJ group performed jumps from a standing start position with instructions to gain maximum jump height. Post training, both groups experienced improvements in vertical jump height \( (p < 0.05) \) and agility time \( (p < 0.05) \) and no change in sprint performance \( (p > 0.05) \). There were no differences between the treatment groups \( (p > 0.05) \). The study concludes that both DJ and CMJ plyometrics are worthwhile training activities for improving power and agility in youth soccer players.

**Fong, et al. (2008)** investigated the plantar Pressure distribution during gait on wooden surface with different slipperiness in the presence of contaminants. Fifteen Chinese male performed 10 walking trails on 5m wooded walkway wearing cloth shoe in four contaminated condition (dry, sand , water , oil). A pressure insole system was employed to record the plantar pressure data at 50 Hz . Peak pressure and time – normalised pressure – time integral were evaluated in nine region in comparing walking on slippery to non- slippery surface. The findings suggested that greater toe grip and gentler heel strike are the strategies to adapt to slippery surface such strategies plantar flexed the ankle and metatarsals to achieve a flat foot contact with the ground especially at heel strike in order to shift the ground reaction force to a more vertical direction as the vertical ground reaction force component increased the available ground friction increased and the floor became less slippery. Therefore, human could walk without slip on slippery surface with greater toe grip and gentler heel strike as adaption strategies.

**Harrison, et al. (2008)** conducted a study on male rugby players. They studied the effect of resisted sprint (RS) training on speed and strength performance.
Fifteen male rugby players aged 20.5 (+/- 2.8) years who were proficient in resisted sledge training took part in the study. The subjects were randomly assigned to control or RS groups. The RS group performed two sessions per week of RS training for 6 weeks, and the control group did no RS training. Pre- and post-intervention tests were carried out for 30-m sprint, drop, squat, and rebound jumps on a force sledge system. A laser measurement device was used to obtain velocities and distance measures during all running trials. The results show a statistically significant decrease in time to 5 m for the 30-m sprint for the RS group (p = 0.02). The squat jump and drop jump variables also showed significant increases in starting strength (p = 0.004) and height jumped (p = 0.018) for the RS group from pre- to post-testing sessions. The results suggest that it may be beneficial to employ an RS training intervention with the aim of increasing initial acceleration from a static start for sprinting.

Ronnestad, et al. (2008) conducted a study on professional soccer players to find out the short-term effects of strength and plyometric training on sprint and jumping performance. Subjects involved in the study were randomly divided into 2 groups. In addition to 6 to 8 soccer sessions a week, ST group (n = 6) performed heavy strength training twice a week for 7 weeks. In addition to the same training as the ST group, ST+P group (n = 8) performed a plyometric training programme. The control group (n = 7) only performed 6 to 8 soccer sessions a week. The various tests in the pre-tests and post-tests were 1 repetition maximum (1RM) half squat, countermovement jump (CMJ), squat jump (SJ), 4-bounce test (4BT), peak power in half squat with 20 kg, 35 kg, and 50 kg (PP20, PP35, and PP50, respectively), sprint
acceleration, peak sprint velocity, and total time on 40-m sprint. No significant differences were found between ST+P group and ST group. Thus, the groups were pooled into one intervention group. Except CMJ, the intervention group significantly improved in all measurements while the control group showed significant improvements only in PP20. Significant difference was found in relative improvement between the intervention group and control group in 1RM half squat, 4BT, and SJ. However, no significant difference between groups was observed in PP20, PP35, sprint acceleration, peak sprinting velocity, and total time on 40-m sprint. The results showed that there were no significant performance-enhancing effects of combining strength and plyometric training in professional soccer players concurrently performing 6 to 8 soccer sessions a week compared to strength training alone. However, the results showed that heavy strength training leads to significant gains in strength and power-related measurements in professional soccer players.

Markovic, et al. (2007) conducted a study on effects of sprint and plyometric training on muscle function and athletic performance and to compare them with the training effects induced by standard plyometric training. Male physical education students were assigned randomly to 1 of 3 groups: sprint group (SG; n = 30), plyometric group (PG; n = 30), or control group (CG; n = 33). Maximal isometric squat strength, squat- and countermovement jump (SJ and CMJ) height and power, drop jump performance from 30-cm height, and 3 athletic performance tests (standing long jump, 20-m sprint, and 20-yard shuttle run) were measured prior to and after 10 weeks of training. Both experimental groups trained 3 days a week; SG performed maximal sprints over distances of 10-50 m, whereas PG
performed bounce-type hurdle jumps and drop jumps. Participants in the CG group maintained their daily physical activities for the duration of the study. Both SG and PG significantly improved drop jump performance (15.6 and 14.2%), SJ and CMJ height (approximately 10 and 6%), and standing long jump distance (3.2 and 2.8%), whereas the respective effect sizes (ES) were moderate to high and ranged between 0.4 and 1.1. In addition, SG also improved isometric squat strength (10%; ES = 0.4) and SJ and CMJ power (4%; ES = 0.4, and 7%; ES = 0.4), as well as sprint (3.1%; ES = 0.9) and agility (4.3%; ES = 1.1) performance. They concluded that short-term sprint training produces similar or even greater training effects in muscle function and athletic performance than conventional plyometric training. This study provided support for the use of sprint training as an applicable training method for improving explosive performance of athletes in general.

Little, et al. (2005) conducted a study on specificity of acceleration, maximum speed, and agility in professional soccer players. High-speed actions are known to impact soccer performance and can be categorised into actions requiring maximal speed, acceleration, or agility. Contradictory findings have been reported as to the extent of the relationship between the different speed components. This study comprised 106 professional soccer players who were assessed for 10-m sprint (acceleration), flying 20-m sprint (maximum speed), and zig-zag agility performance. Although performances in the three tests were all significantly correlated (p < 0.0005), coefficients of determination (r²) between the tests were just 39, 12, and 21% for acceleration and maximum speed, acceleration and agility, and maximum speed and agility, respectively. Based on the low coefficients of
determination, it was concluded that acceleration, maximum speed, and agility are specific qualities and relatively unrelated to one another. The findings suggest that specific testing and training procedures for each speed component should be utilised when working with elite players.

**Kemmler, et al. (2004)** determined the effects on intense exercise on physical fitness, bone mineral density BMD back pain and blood lipids in early post-menopausal women. The study population comprised 50 fully compliant women with no medication or illness affecting bone metabolism, who exercised over 26 months exercise group (EG) two group training session per week and cardiovascular performance. Bone mineral density was measured at the lumbar spine (dual – energy x-ray absorption) [DXA] and quantitative computed tomography (QCT) the proximal femur (DXA) and forearm (DXA) in serum samples taken from a subset of study participants. They determined bone formation (serum of the study participants determined bone formation osteocalcin) and resorption (serum cross – links) markers as well as blood lipid levels. Vasomotor symptoms related to menopause and pain were also assessed. It was found that general purpose exercise programmes with special emphasis on bone density can significantly improve strength and endurance and reduce bone loss, back pain and lipid levels in osteopenic women in their critical early postmenopausal years.

**Luebbers, et al. (2003)** conducted a study on effects of plyometric training and recovery on vertical jump performance and anaerobic power. They examined the effects of 2 plyometric training programmes, equalised for training volume, followed by a 4-week recovery period of no plyometric training on anaerobic power
and vertical jump performance. Physically active, college-aged men were randomly assigned to either a 4-week (n = 19, weight = 73.4 +/- 7.5 kg) or a 7-week (n = 19, weight = 80.1 +/- 12.5 kg) programme. Vertical jump height, vertical jump power, and anaerobic power via the Margaria staircase test were measured pre-training (PRE), immediately post-training (POST), and 4 weeks post-training (POST-4). Vertical jump height decreased in the 4-week group PRE (67.8 +/- 7.9 cm) to POST (65.4 +/- 7.8 cm). Vertical jump height increased from PRE to POST-4 in 4-week (67.8 +/- 7.9 to 69.7 +/- 7.6 cm) and 7-week (64.6 +/- 6.2 to 67.2 +/- 7.6 cm) training programmes. Vertical jump power decreased in the 4-week group from PRE (8,660.0 +/- 546.5 W) to POST (8,541.6 +/- 557.4 W) with no change in the 7-week group. Vertical jump power increased PRE to POST-4 in 4-week (8,660.0 +/- 546.5 W to 8,793.6 +/- 541.4 W) and 7-week (8,702.8 +/- 527.4 W to 8,931.5 +/- 537.6 W) training programmes. Anaerobic power improved in the 7-week group from PRE (1,121.9 +/- 174.7 W) to POST (1,192.2 +/- 189.1 W) but not the 4-week group. Anaerobic power significantly improved PRE to POST-4 in both groups. There were no significant differences between the 2 training groups. Four-week and 7-week plyometric programmes are equally effective for improving vertical jump height, vertical jump power, and anaerobic power when followed by a 4-week recovery period. However, a 4-week programme may not be as effective as a 7-week programme if the recovery period is not employed.

Pinnington, et al. (2001) compared the energy cost (EC) (j x kg (-1) x m (-1)) of running on grass and soft dry beach sand. Seven male and 5 female recreational runners performed steady state running trials on grass in shoes at 8, 11
and 14 km x h(-1). Steady state sand runs, both barefoot and in shoes, were also attempted at 8 km x h(-1) and approximately 11 km x h(-1). One additional female attempted the grass and sand runs at 8 km x h(-1) only. Net total EC was determined from net aerobic EC (steady state VO\(_2\), VCO\(_2\) and RER) and net anaerobic EC (net lactate accumulation). When comparing the surface effects (grass, sand bare foot and sand in shoes) of running at 8 km x h(-1) (133.3 m x min(-1)) in 9 subjects who most accurately maintained that speed (133.3 +/- 2.2 m x min(-1)), no differences (P>0.05) existed between the net aerobic, anaerobic and total EC of sand running barefoot or in shoes, but these measures were all significantly greater (P<0.05) than the corresponding values when running on grass. Similarly, when all running speed trials (n = 87) performed by all subjects (n = 13) for each surface condition were combined for analysis, the sand bare foot and sand in shoes values for net aerobic EC, net anaerobic EC and net total EC were significantly greater (P<0.001) than the grass running measures, but not significantly different (P>0.05) from each other. Expressed as ratios of sand to grass running EC coefficients, the sand running barefoot and sand in shoes running trials at 8 km x h(-1) revealed values of 1.6 and 1.5 for net aerobic EC, 3.7 and 2.7 for net anaerobic EC and 1.6 and 1.5 for net total EC respectively. For all running speeds combined, these coefficients were 1.5 and 1.4 for net aerobic EC, 2.5 and 2.3 for net anaerobic EC and 1.5 and 1.5 for net total EC for sand running barefoot and in shoes respectively. Sand running may provide a low impact, but high EC training stimulus.

**Young, et al. (2001)** conducted a study on specificity of sprint and agility training methods. The purpose of this study was to determine if straight sprint
training transferred to agility performance tests that involved various change-of-direction complexities and if agility training transferred to straight sprinting speed. Thirty-six males were tested on a 30-m straight sprint and 6 agility tests with 2-5 changes of direction at various angles. The subjects participated in 2 training sessions per week for 6 weeks using 20-40-m straight sprints (speed) or 20-40-m change-of-direction sprints (3-5 changes of 100 degrees) (agility). After the training period, the subjects were retested, and the speed training resulted in significant improvements (p < 0.05) in straight sprinting speed but limited gains in the agility tests. Generally, the more complex the agility task, the less the transfer from the speed training to the agility task. Conversely, the agility training resulted in significant improvements in the change-of-direction tests (p < 0.05) but no significant improvement (p > 0.05) in straight sprint performance. They concluded that straight speed and agility training methods are specific and produce limited transfer to the other. These findings have implications for the design of speed and agility training and testing protocols.

Rimmer, et al. (2000) conducted a study to investigate the effects of a sprint-specific plyometrics programme on sprint performance. For this an 8-week training study consisting of 15 training sessions was conducted. Twenty-six male subjects completed the training. A plyometrics group (N = 10) performed sprint-specific plyometric exercises, while a sprint group (N = 7) performed sprints. A control group (N = 9) was included. Subjects performed sprints over 10- and 40-m distances before (Pre) and after (Post) training. For the plyometrics group, significant decreases in times occurred over the 0-10-m (Pre 1.96 +/- 0.10 seconds,
Post 1.91 +/- 0.08 seconds, p = 0.001) and 0-40-m (Pre = 5.63 +/- 0.18 seconds, Post = 5.53 +/- 0.20 seconds, p = 0.001) distances, but the improvements in the sprint group were not significant over either the 0-10-m (Pre 1.95 +/- 0.06 seconds, Post 1.93 +/- 0.05 seconds) or 0-40-m distance (Pre 5.62 +/- 0.14 seconds, Post 5.55 +/- 0.10 seconds). The magnitude of the improvements in the plyometrics group was, however, not significantly different from the sprint group. The control group showed no changes in sprint times. There were no significant changes in stride length or frequency, but ground contact time decreased at 37 m by 4.4% in the plyometrics group only. It was concluded that a sprint-specific plyometrics programme can improve 40-m sprint performance to the same extent as standard sprint training, possibly by shortening ground contact time.

2.3 SUMMARY OF THE REVIEW

In this study 58 reviews were collected from the earlier studies in connection with the present study. The collected review ranged from the year 1979 to 2017. Out of 58 reviews, 28 were regarding critical literature i.e. reviews were related to the independent variable of the study. Remaining 30 reviews were regarding allied literature i.e. it were related to the effect on the concerned dependent variables of the study because of other training effects.