Chapter-II

REVIEW OF RELATED LITERATURE

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 researcher scholar has gone through the available related literature, which are relevant to the present study and have been presented in this chapter.

In this chapter, a review of the literature relevant to this study is presented in the following three sections.

1. Studies on Plyometric Trainnig
2. Studies on Resistance Training
3. Studies on Cross Training

2.1 STUDIES ON PLYOMETRIC TRAINING

Jastrzebski et al., (2014) determined the effects of a six-week plyometric high and low-intensity training on the explosive power of lower limbs in volleyball players. The research was conducted on a sample of 30 volunteers of the Sports Club at Gdansk University of Technology in Gdansk. Before the experiment, the players were divided into two homogeneous groups. After two weeks of an introductory common stage, each group followed a plyometric regime of different intensity. The results showed that the high-intensity program was more efficient than the low-intensity program in developing the explosive power in the volleyball players. The largest significant improvement was observed for the vertical jump with arm swing (11% in HIJG and 3.8% in LISG). The strongest correlations were registered for the maximal power and the total mechanical work obtained in the Wingate test (r=0.83), and the power of jumps during attacks and blocks (r=0.78). The experiment confirmed high effectiveness of the training loads applied in the experiment, in particular in the high-intensity program.

Campillo et al., (2014) investigated the efficiency of short-term vertical plyometric training program within soccer practice to improve both explosive actions and endurance in young soccer players. Seventy-six players were recruited and assigned either to a training group (TG; n = 38; 13.2 ± 1.8 years) or a control group (CG; n = 38; 13.2 ± 1.8 years) group. All players trained twice per week, but the TG followed a 7-week plyometric program implemented within soccer practice, whereas the CG followed regular practice. Twenty-meter sprint time (20-m), Illinois agility test time, countermovement jump (CMJ) height, 20- (RSI20) and 40- (RSI40) cm drop jump reactive strength index, multiple 5 bounds distance (MB5), maximal kicking test for distance (MKD), and 2.4-km time trial were measured before and after the 7-week period. Plyometric training induced significant (p 0.05) and small to moderate standardized effect (SE) improvement in the CMJ (4.3%; SE = 0.20), RSI20 (22%; SE = 0.57), RSI40 (16%; SE = 0.37), MB5 (4.1%; SE = 0.28), Illinois agility test time (-3.5%, SE = -0.26), MKD (14%; SE = 0.53), 2.4-km time trial (-1.9%; SE = -0.27) performances but had a trivial and no significant effect on 20-m sprint time (-0.4%; SE = -0.03). No significant improvements were found in the CG. An integrated vertical plyometric program within the regular soccer practice can substitute soccer drills to improve most explosive actions and endurance, but horizontal exercises should also be included to enhance sprinting performance.

Singh et al., (2014) compared the effects of a 4-week plyometric training on two different surfaces, sand and grass on muscle soreness and selected sport-specific performance variables in national level hockey players. Subjects were randomly divided into two groups-grass training group (N=20) and sand training group (N=20). After the baseline measurements of strength, endurance, balance, and agility, plyometric training was given for 4-weeks,three sessions per week. Muscle soreness was assessed at the end of each training session on a 7-point likert scale. Post-readings of strength, endurance, balance and agility were taken after the 4-week training programme. Data when compared after plyometric training revealed no significant changes between two groups ($p>0.05$), however players in the sand group experienced less muscle soreness ($p<0.05$) than grass group. There was significant improvement ($p<0.05$) seen in the tested variables in both groups after the training but no significant interaction was found between the two surfaces after the training. These findings suggest that short-term plyometric training on sand/non-rigid surface induces similar improvements in strength, endurance, balance and agility as on firm surface but induces significantly less muscle soreness. Hence, plyometric training on sand is viable option for coaches to enhance performance in athletes, while reducing risk of muscle soreness and damage.

Soumitra and Wondirad (2014), examined the effect of six week plyometric training on vertical jump performance of Maychew athletes. Height, weight, BMI and age were measured; in a pre and post test vertical jump test was conducted and also six week plyometric training protocol was given to the athletes. Twenty male (Mean ± SD) age: 18.45 ± 1.73 yrs; height 1.69 ±.079meter; weight 56.75 ± 6.04 Kg: Body Mass Index (BMI) 19.85 ± 1.65 and thirty female age: 17.33 ± 1.99 yrs; height 1.56 ± .076 meter; weight 45.17 ± 5.95Kg: BMI 18.7 ± 1.59. Paired sample t- test; $t(49) = 3.734$, $p < .001$ demonstrates that plyometric training significantly improve the vertical jump performance of an athlete.

Rde et al., (2014) studied the effects of plyometric training on lower limb kinematics, eccentric hip and knee torques, and functional performance. For this study thirty-six females were divided into a training group (TG; n = 18) that carried out the plyometric training for 8 weeks, and a control group (CG; n = 18) that carried out no physical training. Twenty-four plyometric training sessions approximately 8 weeks with 3 sessions per week on alternate days were given. Lower limb kinematics (maximum excursion of hip adduction, hip medial rotation, and knee abduction during the single leg squat), eccentric hip (abductor, adductor, medial, and lateral rotator) isokinetic peak torques and knee (flexor and extensor) isokinetic peak torques, and functional performance (triple hop test and the 6-m timed hop test) were selected as variables. After 8 weeks, only the TG significantly reduced the values for the maximum excursion of knee abduction (P = 0.01) and hip adduction (P < 0.001). Similarly, only the TG significantly increased the eccentric hip abductor (P < 0.001) and adductor (P = 0.01) torques. Finally, only the TG significantly increased the values in the triple hop test (P < 0.001) and significantly decreased the values in the 6-m timed hop test (P < 0.001) after intervention. It was concluded Plyometric training altered lower limb kinematics and increased eccentric hip torque and functional performance, suggesting the incorporation of these exercises would save as preventive programs for ACL injuries.

Campillo et al., (2014) examined the effect of a short-term plyometric training program on explosive strength and endurance performance in highly competitive middle- and long-distance runners. Athletes were randomly assigned to a control group (CG, n = 18, 12 men) and an explosive strength training group (TG, n = 18, 10 men). Drop jump (DJ) from 20 (DJ20) and 40 cm (DJ40), countermovement jump with arms (CMJA), 20-m sprint time, and 2.4-km endurance run time test were carried out before and after 6 weeks of explosive strength training. Also, the combined standardized performance (CSP) in the endurance and explosive strength test was analyzed. After intervention, the CG did not show any significant change in performance, whereas the TG showed a significant reduction in 2.4-km endurance run time (-3.9%) and 20-m sprint time (-2.3%) and an increase in CMJA (+8.9%), DJ20 (+12.7%), and DJ40 (16.7%) explosive performance. Strength training group also exhibited a significant increase in CSP, although the CG showed significant reduction. Thus, the result was concluded that properly programmed concurrent explosive strength and endurance training could be advantageous for middle- and long-distance runners in their competitive performance, especially in events characterized by sprinting actions with small time differences at the end of the race.

Devaraju (2014) evaluated the effect of plyometric training on explosive strength among Kabaddi players. For the present study 30 male Kabaddi players from Dr. SivanthiAditanar College of Physical Education, Tiruchendur, Tamilnadu were selected at random and their age ranged from 18 to 25 years. The subjects selected were randomly assigned into control and experimental groups of fifteen each and named as Group 'A' and Group 'B'. Group 'A' underwent plyometric training and Group 'B' underwent no training. The data was collected before and after six weeks of training and analyzed by applying Analysis of Co-Variance (ANCOVA) to find out the effect of plyometric training programme. The level of significance was set at 0.05. The findings of the study had strongly indicated that plyometric training of six weeks had significant effect on explosive strength of kabaddi players. Hence the hypothesis set that plyometric training programmewould have been significant effect on explosive strength in light of the same the hypothesis is accepted. Significant effect of plyometric training was found on explosive strength.

Asaithambi et al., (2014) found out the effect of different intensities of plyometric exercises on explosive power of Collegiate athletes. To achieve this purpose 40 college athletes studying various colleges in Chennai, Tamilnadu, India were selected as subjects. Their age was ranged from 18 to 25 ears. The subjects were divided into two groups of twenty each (n=20). Group-I underwent low intensity plyometric training (LIPTG) and Group-II underwent High intensity plyometric training (HIPTG). The duration of the training period was restricted to twelve weeks and the number of sessions per week was confined to three. Explosive Power was selected as criterion variable and it was assessed by vertical jump test. The data collected from the experimental groups were statistically examined using Analysis of covariance (ANCOVA). The results indicated that the explosive power showed significant difference between the groups.

Makaruk et al., (2014) examined the chronic effects of single and repeated jumps training on vertical landing force (VGRF) and jump height in untrained men. The VGRF and jump height were compared after a six-week plyometric training programme containing single and repeated jumps, together with two additional parameters: landing time (LT) and range of the knee flexion during landing (KF). Thirty-six untrained physical education students with a plyometric training background were randomly assigned to a single jump group (SJG, n =12), repeated jumps group (RJG, n =12), and control group (CON, n =12). The SJG performed only single jumps, the RJG executed repeated (consecutive) jumps, whereas the CON did not perform any exercises at all. A countermovement jump (CMJ), repeated countermovement jumps (RCMJ), and a drop jump (DJ) were tested before and after the training. Only the RJG showed a significantly reduced VGRF ($p<0.05$) in all tests. Both plyometric groups significantly improved ($p<0.05$) their jump height in all tests. The LT was significantly greater in the RJG, compared to the SJG, in all tests. The KF was also significantly ($p<0.05$) greater in the RJG than the SJG for CMJ and RCMJ. The results suggested that repeated jumps were beneficial for simultaneous landing force reduction and jumping performance enhancement.

Vaczi et al., (2013) investigated the effects of a short-term in-season plyometric training program on power, agility and knee extensor strength. Male soccer players from a third league team were assigned into an experimental and a control group. The experimental group, beside its regular soccer training sessions, performed a periodized plyometric training program for six weeks. The program included two training sessions per week, and maximal intensity unilateral and bilateral plyometric exercises (total of 40-100 foot contacts/session) were executed. Controls participated only in the same soccer training routine, and did not perform plyometrics. Depth vertical jump height, agility (Illinois Agility Test, T Agility Test) and maximal voluntary isometric torque in knee extensors using Multicont II dynamometer were evaluated before and after the experiment. In the experimental group small but significant improvements were found in both agility tests, while depth jump height and isometric torque increments were greater. The control group did not improve in any of the measures. Results of the study indicate that plyometric training consisting of high impact unilateral and bilateral exercises induced remarkable improvements in lower extremity power and maximal knee extensor strength, and smaller improvements in soccer-specific agility. Therefore, it is concluded that short-term plyometric training should be incorporated in the in-season preparation of lower level players to improve specific performance in soccer.

Arazi et al., (2013) compared the effects of high, moderate and low intensity plyometric exercise on the post-exercise systolic and diastolic blood pressure and heart rate responses. Ten healthy normotensive men (age, 21.1±0.9 years; height, 175.8±6 cm; and body mass, 69.1±13.6 kg) volunteered to participate in this study and were evaluated for three non-consecutive days in depth jump exercise from 20-cm box (low intensity [LI]), 40-cm box (moderate intensity [MI]) and 60-cm box (high intensity [HI]) for 5 sets of 20 repetitions. After each exercise session, systolic blood pressure (SBP), diastolic blood pressure (DBP) and heart rate (HR) were measured every 10 min for a period of 90 min. No significant differences were observed among post-exercise SBP, DBP and HR when the protocols (LI, MI and HI) were compared. The LI and HI protocols showed greater reduction in SBP at 40(th)-70(th) min of post-exercise (~9%), whereas the LI and MI protocols indicated greater reduction in DBP at 10(th)-50(th) min of post exercise (~10%). In addition, the change in the DBP for HI was not significant and the increases in the HR were similar for all intensities. It can be concluded that a plyometric exercise (PE) can reduce SBP and DBP post-exercise and therefore we can say that PE has significant effects for reducing BP and HR or post-exercise hypotension.

Vassil andBazanov (2012) found out the efficiency of composed plyometric training program on youth volleyball players force capabilities in their usual training period. The plyometric training program was applied during 16 week period where was attended twenty-one 12-19 years old youth volleyball players. Twelve of them were female and nine male volleyball players. There were three control testings. All subjects participated in following tests: standing long jump, depth leap long jump, medicine ball throws up in 10 seconds, medicine ball overhead throws forward against the wall in 10 seconds, maximal vertical jumps to the maximal height in 10 seconds, maximal vertical jump height. Testing results statistical analysis has shown athletes legs and arms speed force reliable improvement. Standing long jump, depth leap long jump and maximal vertical jump height test results, what has shown legs explosive power, has not shown remarkable reliable difference ($P>0.05$). Medicine ball throws and maximal vertical jumps to the maximal height in 10 seconds, what show speed force improvement, showed reliable difference ($P<0.01$).

2.2 STUDIES ON ANAEROBIC TRAINING

Wang et al, (2014) investigated and compared the effects of an eight-week program of whole body vibration combined with counter-movement jumping (WBV + CMJ) or counter-movement jumping (CMJ) alone on players. Twenty-four men's volleyball players of league A or B were randomized to the WBV + CMJ or CMJ groups (n = 12 and 12; mean [SD] age of 21.4 [2.2] and 21.7 [2.2] y; height of 175.6 [4.6] and 177.6 [3.9] cm; and weight, 69.9 [12.8] and 70.5 [10.7] kg, respectively). The pre- and post-training values of the following measurements were compared: H-reflex, first volitional (V)-wave, rate of electromyography rise (RER) in the triceps surae and absolute rate of force development (RFD) in plantar flexion and vertical jump height. After training, the WBV + CMJ group exhibited increases in H reflexes ($p = 0.029$ and <0.001); V-wave ($p < 0.001$); RER ($p = 0.003$ and <0.001); jump height ($p < 0.001$); and RFD ($p = 0.006$ and <0.001). The post-training values of V wave ($p = 0.006$) and RFD at 0-50 ($p = 0.009$) and 0-200 ms ($p = 0.008$) in the WBV + CMJ group were greater than those in the CMJ group. This study shows that a combination of WBV and power exercise could impact neural adaptation and leads to greater fast force capacity than power exercise alone in male players.

Keiner et al., (2014) analyzed the possible correlations between the 1-Repetition Maximum/body mass (SREL) in the front and back squats and COD. The subjects (n = 112) were between 13 and 18 years of age and divided into 2 groups with 4 subgroups (A = under 19 years of age, B = under 17 years of age, and C = under 15 years of age). For approximately 2 years, 1 group (control group [CG]) only participated in routine soccer training, and the other group (strength training group [STG]) participated in an additional strength training program with the routine soccer training. Additionally, the performances in the COD of 34 professional soccer players of the first and second divisions in Germany were measured as a standard of high-level COD. For the analysis of the performance development within a group and pair wise comparisons between 2 groups, an analysis of variance with repeated measures was calculated with the factors group and time. Relationships between the COD and SREL were calculated for the normal distributed data using a plurality of bivariate correlations by Pearson. The data showed that additional strength training over a period of 2 years significantly affected the performance in the COD. The STG in all subcohorts reached significantly ($p < 0.05$) faster times in the COD than did the CG. The STG amounted up to 5% to nearly 10% better improvements in the 10-m sprint times compared with that of the CG. Furthermore, the data show significant ($p < 0.05$) moderate to high correlations ($r = -0.388$ to -0.697) between the SREL and COD and long-term strength training improved the performance of the COD. Therefore, long-term resistance training was recommended early as in childhood and adolescence as possible.

Nageswaran (2014) found out the effects of resistance band training on strength, speed and balance among Inter collegiate

Kabaddi players. Twenty four male inter collegiate Kabaddi players studying in SivanthiAditanar College of Physical Education, Tiruchendur were randomly selected as subjects. The age of the subjects ranged from 21 to 28 years. The selected subjects were divided into two groups. Group I underwent resistance band training and Group II acted as control. The experimental group was subjected to resistance band training for alternate three days in a week for six weeks. The resistance band training was selected as independent variable and the criterion variables such as strength, speed and balance were selected as dependent variables. Strength was assessed by 1 repetition test, speed was assessed by 50m run and balance was assessed by stork stand test. The experimental design selected for this study was pre and post test randomized design. The data were collected from all the subjects before and after the training period and statistically analyzed by using dependent 't' test and analysis of covariance (ANCOVA). It was found that there was a significant improvement and significant existed due to the effect of resistance band training on strength, speed and balance among inter collegiate Kabaddi players when compared to control group.

Freitas et al., (2014) assessed the sensitivity of; performance in the countermovement vertical Jump (CMJ); the Recovery and Stress Questionnaire for Athletes (RESTQ-Sport); the Total Quality Recovery Scale (TQR) and the creatine kinase (CK) to the deliberate intensification of volleyball training loads. For this purpose 8 athletes underwent a training period (FP) of 11 days of deliberate training load

(TL) intensification followed by a second period (SP) of 14 days of reduction of loads (IT group). A further 8 athletes continued training with normal TL (NT group). Both groups were tested before the FP (baseline), after the FP and after the SP. The TL evaluated using the session rating of perceived exertion method (session-RPE) was higher after the FP compared to the SP, and higher in the IT group, compared to the NT group. The CMJ did not change in either group ($p > 0.05$). In the IT group, the RESTQ-Sport was altered after the FP compared to both the baseline and the SP ($p < 0.05$), while no change was observed in the NT group. In the IT group, the CK increased and the TQR decreased after the FP compared to both the baseline and after the SP and were higher and lower, respectively, than the NT group ($p < 0.05$). The results suggest that performance in the CMJ is not a sensitive variable to the fatigue caused by intensification of training loads during a pre-competitive period in volleyball, whereas CK, TQR and RESTQ-Sport were shown to be sensitive measures.

Silva et al., (2014) compared volume load and markers of muscle damage after resistance exercise using two load reduction strategies versus a constant intensity. For this purpose Twenty-seven trained men (age = 23.4±3.5 years, body mass = 74.5±10.7 Kg, height = 174±8 cm, 10 RM = 211±40 Kg) completed one weekly bout of 4 sets of leg press exercise under three loading schemes in a randomized, counterbalanced order over a three-week period were selected. The loading schemes were (a) constant load for all sets (CON), (b) 5% load reduction after each set (LR5), and (c) 10% load reduction after each

set (LR10). Volume load, muscle soreness (SOR), and range of motion (ROM) at the knee were assessed after each bout. Results: Volume load was significantly different amongst all conditions (CON = 6799±1583 Kg; LR5 = 8753±1789 Kg; 10896±2262 Kg; F= 31,731; p<0.001). ROM and SOR were significantly different among conditions, with LR5 and LR10 producing greater preservations of ROM (p =<0.001) and less SOR (p < 0.001). These data may support the use of
load reductions when training for hypertrophy.

Bolger et al., (2014) found out the effects different forms of resistance-based training have on sprinting performance in competitive sprinters. Specific key words (Sprinters OR Sprint) NOT (Rugby, Soccer, Cycling, Swimming, Paralympic, Nutrition) were used to search relevant databases through November 2013 for related literature. Original research was reviewed using the Physiotherapy Evidence Database (Pedro) scale. Five studies met the inclusion criteria: actively competitive adult male sprinters who participated in a resistance-based intervention (>4 weeks), with outcome measures in the form of 10-100 m sprint times. Exclusion criteria included acute studies (<4 weeks), non-sprinting populations and studies with no performance outcome measures (10-100 m sprint times). Three of the five studies employed both loco motor resistance and fixed plane resistance, whereas the remaining two studies used more fixed plane resistance e.g. squat and leg extension. Three of the studies showed a statistical improvement in sprinting performance measures e.g. a decrease in 30 m sprint time (p=0.044), whereas one study showed a decrease in sprinting performance. The analysis concluded that resistance-based training has a positive effect on sprinting performance. Varied input of loco motor resistance and fixed plane resistance has resulted in similar percentage change for sprinting performance. This review adds to the body of knowledge by strongly highlighting the dearth of literature exploring the effects of resistance-based training on sprinting performance in competitive sprinters. The short duration and wide range of exercises implemented in studies to date are of concern, but coaches should not hesitate to implement well-planned resistance programs for their sprint athletes.

Vechin et al., (2014) compared the effects of LRT-BFR and HRT on quadriceps muscle strength and mass in elderly. Twenty-three elderly individuals, 14 men and nine women (age: 64.04 ± 3.81 years; weight: 72.55 ± 16.52 Kg; height: 163 ± 11cm), undertook 12 weeks of training. Subjects were ranked according to their pre-training quadriceps cross-sectional area (CSA) values and then randomly allocated into one of the following groups: (1) control group (CG); (2) HRT: 4 X 10 repetitions 70-80% 1-RM; (3) LRT-BFR: 4 sets (1 x 30 and 3 x 15 repetitions) 20-30% 1-RM. The occlusion pressure was set at 50% of maximum tibial arterial pressure and sustained during the whole training session. Leg-press 1-RM and quadriceps CSA were evaluated at pre- and post-training. A mixed-model analysis was performed and the significance level was set at P0.05. Both training regimes were effective in increasing pre- to post-training leg-press 1-RM (HRT: 54 %, $P < 0.001$; LRT-BFR: 17 %, P =

0.067) and quadriceps CSA (HRT: 7.9 %, $P < 0.001$; LRT-BFR: 6.6 %, $P < 0.001$), however, HRT seems to induce greater strength gains. In summary, LRT-BFR constitutes an important surrogate approach to HRT as an effective training method to induce gains in muscle strength and mass in elderly.

Neto et al., (2014) compared the acute effect of resistance exercise (RE) with and without blood flow restriction (BFR) on heart rate (HR), double product (DP), oxygen saturation (SpO_2) and rating of perceived exertion (RPE). Twenty-four men (21·79 ± 3·21 years) performed three experimental protocols in a random order (crossover): (i) high-intensity RE at 80% of 1RM (HI), (ii) low-intensity RE at 20% of 1RM (LI) and (iii) low-intensity RE at 20% of 1RM combined with partial blood flow restriction (LI+BFR). HR, blood pressure, SpO_2 and RPE were assessed. The data were analyzed using repeated measures analysis of variance and the Wilcox on test for RPE. The results indicated that all protocols significantly increased HR, both immediately post exercise and during the subsequent 60 min (P<0·05), and post exercise DP (P<0·05), but there were no differences between protocols. The protocols of LI and LI+BFR reduced post exercise SpO_2 (P = 0·033, P = 0·007), and the LI+BFR protocol presented a perception of greater exertion in the lower limbs compared with HI (P = 0·022). We conclude that RE performed at low intensity combined with BFR seems to reduce the SpO_2 after exercise and increase HR and DP while maintaining a perception of greater exertion on the lower limbs.

Kjolhede et al., (2014) evaluated potential changes in functional capacity and neuromuscular function after 24 weeks of supervised PRT, and whether improvements are maintained after an additional 24 weeks of self-guided exercise. This study was a randomized controlled trial, with a training group and a waitlist group undergoing supervised PRT for 24 weeks initially or after 24 weeks of habitual lifestyle, respectively. Functional capacity, isometric muscle strength of knee extensors and flexors, neural drive and thigh muscle cross-sectional area was measured at baseline, after 24 and 48 weeks. The training group significantly improved neuromuscular function of the knee extensors and flexors, which translated to improvements in functional capacity. Furthermore, the improved functional capacity was maintained after 24 weeks of self-guided physical activity. The waitlist group produced similar patterns of changes after PRT. Compelling evidence is provided, that PRT performed over sufficiently long periods, improves functional capacity, likely due to neuromuscular adaptations.

Garcia et al., (2014) compared the effects of multiple-set (MS) and tri-set (TS) RT approaches on muscle strength and body composition following a 12 week programme in trained women (> 1 year of RT experience). A secondary objective was to assess variations in individual responsiveness to the RT by the identification of high (strength gains were > 20%), moderate (10 and 19%) and low responding (< 10%) subjects. Eleven healthy experientially resistance trained women were randomly divided into two groups: MS (n = 6; age

27·17 ± 8·23 years; body mass 57·97 ± 2·48 kg) and TS (n = 5; age 23·20 ± 2·28 years; body mass 61·74 ± 6·95 kg). High responders were found in the training groups (MS n = 4 and TS n = 1), moderate (MS n = 1 and TS n = 3) and low responders (MS n = 1 and TS n = 1). The MS group displayed an increase in squat 1RM (P<0·01), stiff leg dead lift 1RM (P<0·002) and squat repetitions maximum at 50% of 1RM (P<0·04). The TS method significantly increased all strength variables (P<0·05), with no differences between methods (P>0·05). Differences were evident between subjects classified as high, medium and low responding in the stiff leg dead lift 1RM (P = 0·007). Both RT protocols increased strength, with no effect on body composition. The variability in individual responsiveness emphasizes the importance of individualized RT prescription for strength practitioners.

Hong et al., (2014) found out the changes in muscle mass and strength across the adult age span are variable and related to the ciliaryneurotrophic factor (CNTF) genotype. In particular, a single CNTF haplotype (1357 G A) is important for neuronal and muscular developments and may be associated with muscle strength response to resistance training. We examined whether CNTF genotype differentially influences the effect of resistance training on neuromuscular improvement in male college students. Resistance training of the upper extremities comprised 3 sets at 75%-85% intensity per 1 repetition maximum, 3 times a week, for a total of 8 weeks. We measured iso kinetic muscle function of the elbow joint with regard to strength (60°/s) and endurance (180°/s) by using an isokinetic dynamometer. The biceps brachii (BB) and brachioradialis muscles were studied using surface electromyography with spike-triggered averaging to assess surface-detected motor unit potential (SMUP) area. After resistance training, the SMUP of the BB increased significantly at 60°/s ($p < 0.05$), but no difference in the CNTF genotype was observed. The SMUP of the BB at 180°/s increased significantly in the GG/AA genotype group compared with that in the GA genotype group ($p < 0.05$). The average power of the elbow flexor at 180°/s increased significantly after resistance training ($p < 0.05$), but again, no difference in the CNTF genotype was observed. Thus, improvements in muscle strength and endurance may have resulted directly from resistance training rather than from genetic factors related to nerves in muscle tissue. Key Points Resistance training improves muscle strength and endurance in young men. This improvement in muscular strength and endurance is irrespective of CNTF genotypes.

Nicholson et al., (2014) determined the effect of 26 weeks of low-load high-repetition resistance training (Body Pump™) on maximal strength, gait speed, balance and self-reported health status in healthy, active middle-aged and older adults. Sixty-eight apparently healthy, active adults aged over 55 years completed either 26 weeks of Body Pump™ training (PUMP) or served as control participants (CON). The Body Pump™ group (n=32, age=66±4 years) trained twice per week for 26 weeks while the control group (n=36, age=66±5 years) continued with their normal activities. Leg-press and Smith-machine bench-press one repetition maximum (1RM), gait speed, balance, and self-reported health status were all assessed at baseline and follow-up. Significant group-by-time interactions in favour of the Body Pump™ group were found for leg-press 1RM (PUMP +13%, CON +3%, $p=0.007$, partial $eta^2=0.11$), Smith-machine bench-press 1RM (PUMP +14%, CON +5%, $p=0.001$, partial $eta^2=0.18$), normal gait speed (PUMP +23%, CON +9%, $p=0.028$, partial $eta^2=0.08$) and single leg balance right (PUMP +24%, CON -7%, $p=0.006$, partial $eta^2=0.12$). There were no group-by-time interactions for health status measures. Three participants in the Body Pump™ group withdrew from training due to injury or fear of injury related to training. Low-load high-repetition resistance training in the form of Body Pump™ is effective at improving maximal strength, gait speed and some aspects of standing balance in adults over 55 years. The training was well tolerated by the majority of participants.

2.3 STUDIES ON CROSS TRAINING

Taheri et al., (2014) investigated the effect of plyometric and resistance training on agility, speed and explosive power in soccer players. 30 male soccer players who aged 18-25 voluntarily participated in the study. They were randomly assigned in plyometric (n=15) and resistance (n=15) groups. Both groups performed selected soccer-specified plyometric and resistance training for 8 weeks. Data was analyzed using paired t-test, independent t-test, and covariance statistical methods. The results showed that levels of agility, speed, and explosive power in plyometric training group (p=0.0001), and agility and explosive power in resistance training group (p=0.0001) were significantly improved in post-test compared to pre-test. Between-groups comparison showed better records in agility, speed and explosive power for plyometric compared with resistance training group after eight weeks (respectively p=0.032, p=0.0001 and p=0.002). According to the results, it can be concluded that both plyometric and resistance training exercises increase agility and explosive power and reduce sprint time in football players. Plyometric exercises also showed more favorable effects on study variables compared with resistance exercises. Therefore, these types of training methods are suggested to soccer players and coaches for improving speed and performance skill.

Annadurai and SathishBabu (2014) found out the effect of Swiss ball and plyometric training programme on selected physical variable and skill performance of inter collegiate men volleyball players, to achieve that 45 subjects aged from 19 to 28 years from affiliated college of Bharathiar University Coimbatore, Tamilnadu were selected, subjects (N = 45) were divided into three equal groups. Namely, Group - I underwent Swiss ball training group (SBTG), Group - II underwent plyometric training group (PTG), and Group - III acted as control group (CG) was not given any specific training. Each group consists of 15 subjects. They were assessed before and after six weeks in both groups. The analysis of co-variance (ANCOVA) was used to determine any significant difference was present among the three groups of the dependent variables. The study revealed that the selected dependent variables such as speed, flexibility, explosive power, muscular strength and endurance, serving Ability and passing ability have significant improvement due to the Swiss ball and plyometric training programme on selected physical fitness variables and skill performance of inter collegiate men volleyball players.

Kota and Kumar (2014) found out the effect of Plyometric training and Plyometric with Pilates exercises on selected motor ability physiological and skill related performance variables among volleyball players. To achieve the purpose of this study, 60 inter collegiate male volleyball player were selected randomly from in an around Warangal district, Telangana, their age ranged from 18-23 years. They were divided into three equal groups and each group consists of 20 subjects. Group A underwent Plyometric training; Group B underwent Plyometric with Pilates exercise for three days per week for 12 weeks on alternative days and Group C acted as a control who did not involve any special training apart from the regular curricular activities. The collected data were analyzed statistically by using the analysis of variance (ANOVA) to determine the differences, Analysis of covariance (ANCOVA) was used to determine the differences, and the Scheheffe's test was applied as post hoc test to find out paired mean differences. In all cases 0.05 level of confidence was selected to test the hypotheses.

Aghajani et al., (2014) examined the effects of plyometric and resistance training on the explosive power and the amount of young male volleyball players' strength in Guilan province. The participants include 45 volleyball players, 15-2 years old, which were randomly divided into three groups: two training groups and one control group. Among the two training groups, one was engaged in plyometric and the other in resistance exercise training (six weeks, two times per week).The control group was doing its common volleyball training. Variables under measurement consist of strength and explosive power. We found that after a six weeks training, there were significant differences between the average of explosive power and strength in both groups of plyometric and resistance training in comparison to control group (P 0.05). The researcher observed that there was a significant difference in the average of explosive power and strength within both plyometric and weight groups from pre to post-test (p 0.05). The amount of improvement in resistance training group was more than plyometric group.

*Carvalho et al., (2014)*found out the effects of a strength training program combined with specific plyometric exercises on body composition, vertical jump (VJ) height and strength development of lower limbs in elite male handball players. A 12-week program with combined strength and specific plyometric exercises was carried out for 7 weeks. Twelve elite male handball players (age: 21.6 ± 1.73) competing in the Portuguese Major League participated in the study. Besides the anthropometric measurements, several standardized jump tests were applied to assess VJ performance together with the strength development of the lower limbs in an isokinetic setting. No significant changes were found in body circumferences and diameters. Body fat content and fat mass decreased by 16.4 and 15.7%

respectively, while lean body mass increased by 2.1%. Despite small significance, there was in fact an increase in squat jump (SJ), counter movement jump (CMJ) and 40 consecutive jumps after the training period (6.1, 3.8 and 6.8%, respectively). After the applied protocol, peak torque increased in lower limb extension and flexion in the majority of the movements assessed at 90ºs-1. Consequently, it is possible to conclude that combining general strength-training with plyometric exercises can not only increase lower limb strength and improve VJ performance but also reduce body fat content.

Rao and Kishore(2014) assessed the combined effect of strength and plyometric training on selected motor fitness components of male kabaddi players. Forty eight (48) male inter collegiate kabaddi players were selected from affiliated colleges of AcharyaNargarjuna University. These players were classified into two groups namely strength and plyometric training group (SPTG: 24) and control group (CG: 24). In the present study speed, power and agility were selected as dependent variables. 50 yard dash, vertical jump test and shuttle run test was used to measure speed, power and agility. The combined training of strength and plyometric training was administered for ten weeks three days per week. The combined training program consists of a combination of both strength and plyometric training programs in which two sessions a week of plyometric and one strength training sessions in even weeks and one plyometric and two strength training sessions in odd weeks had accomplished. The pre and post data were collected from both SPTG and CG. The collected data was evaluated using Analysis of Covariance (ANCOVA). Paired t test was calculated to assess the changes within a group before and after nine weeks of training intervention. The result of the study clear show that there is significant difference between groups on speed (F = 109.46, p = 0.000) and power (F = 11.57, p = 0.001). However, agility (F = 0.025, p = 0.875) showed no significant difference between the groups. It is inferred that ten weeks of combined strength and plyometric training showed significant improvement in speed and power of male intercollegiate kabaddi players.

Villarreal et al., (2013) compared the effect of five different training stimuli on sprinting ability and strength production. Sixty physical education students were randomly assigned to five experimental groups: all types of training (A), full-squat (B), parallel-squat (C), loaded countermovement jumping (D) and plyometric training (E). Participants in each group trained three days a week for a total of seven weeks. Sprint performance (30m), maximal dynamic strength (1RM) (kg) and velocity of displacement in the concentric phase of full-squat (m/s) were measured before and after seven weeks of training. Pre-training results showed no significant differences among the groups in any of the variables tested. After seven weeks no significant improvement in sprint performance was found, however, significant improvement in maximal dynamic strength, velocity of displacement were observed in all the groups: combined methods group A (20%), heavy-resistance group B (11%), power-oriented group C (17%), ballistic group D (14%) and plyometric group E (6%).A combined training approach using full-squat, parallel-squat, loaded countermovement jumping and plyometric training results in a light improvement in maximal strength, velocity of displacement and sprint performance and the resemblance between movement patterns and the velocity of displacement common to the training and testing methods also contributes to greater performance improvement.

Cherif et al., (2012) investigated the effect of a combined program including sprint repetitions and drop jump training in the same session on male handball players. Twenty-two male handball players aged more than 20 years were assigned into 2 groups: experimental group (n=11) and control group (n=11). Selection was based on variables "axis" and "lines", goalkeepers were not included. The experimental group was subjected to 2 testing periods (test and retest) separated by 12 weeks of an additional combined plyometric and running speed training program. The control group performed the usual handball training. The testing period comprised, at the first day, a medical checking, anthropometric measurements and an incremental exercise test called yo-yo intermittent recovery test. 2 days later, participants performed the Repeated Sprint Ability test (RSA), and performed the Jumping Performance using 3 different events: Squat jump (SJ), Countermovement jump without (CMJ) and with arms (CMJA), and Drop jump (DJ). At the end of the training period, participants performed again the repeated sprint ability test, and the jumping performance. The conventional combined program improved the explosive force ability of handball players in CMJ (P=0.01), CMJA (P=0.01) and DJR (P=0.03). The change was 2.78, 2.42 and 2.62% respectively. No significant changes were noted in performances of the experimental group at the squat jump test and the drop jump with the left leg test. The training intervention also improved the running speed ability of the experimental group (P=0.003). No statistical differences were observed between lines or axes. Additional combined training program between sprint repetition and vertical jump in the same training session positively influence the jumping ability and the sprint ability of handball players.

*MacDonald et al., (2012)*compared the effects of resistance training (RT), plyometric training(PT), and CT on lower body strength and anthropometrics. Thirty recreationally trained college-aged men were trained using 1 of 3 methods: resistance, plyometric, or complex twice weekly for 6 weeks. The participants were tested pre, mid, and post to assess back squat strength, Romanian dead lift (RDL) strength, standing calf raise (SCR) strength, quadriceps girth, triceps surae girth, body mass, and body fat percentage. Diet was not controlled during this study. Statistical measures revealed a significant increase for squat strength (p = 0.000), RDL strength (p = 0.000), and SCR strength (p = 0.000) for all groups pre to post, with no differences between groups. There was also a main effect for time for girth measures of the quadriceps muscle group (p = 0.001), the triceps surae Muscle group (p = 0.001), and body mass (p = 0.001; post hoc revealed no significant difference). There were main effects for time and group × time interactions for fat-free mass % (RT: $p = 0.031$; PT: $p = 0.000$). The results suggest that CT mirrors benefits seen with traditional RT or PT. Moreover, CT revealed no decrement in strength and anthropometric values and appears to be a viable training modality.

Grieco et al., (2012) investigated the effect of a 10-week combined resistance-plyometric training program on the RE and V[Combining Dot Above]O2max in female soccer players. Fifteen Division 1A female soccer players (age 19.0 ± 0.7 years; height 1.67 ± 0.1 m; weight 61.7 ± 8.1 kg) performed a treadmill test for V[Combining Dot Above]O2max and RE at the end of a competitive season (PRE) and after a 10-week training program (POST). Isometric strength was measured in knee flexion and extension. Resistance training was conducted 2 dwk on nonconsecutive days; plyometric training was conducted separately on different nonconsecutive days. Eleven subjects were included in the PRE-POST analysis (age 19.0 ± 0.8 years; height 1.67 ± 0.5 m; weight 59.9 ± 6.7 kg). Descriptive statistics were compared using analysis of variance with repeated measures with a Bonferroni adjustment, and significance was set at $p < 0.05$. A significant increase occurred after training in the V[Combining Dot Above]O2peak (10.5%; $p = 0.008$), time to fatigue (6.9%; $p = 0.017$), and interpolated maximal speed (3.6%; $p = 0.016$), despite there being a decrease in the maximal respiratory exchange ratio (2.9%; $p = 0.001$). There was no significant change in the RE at 9 km·h; however, there was a significant decrease in the percentage of the V[Combining Dot Above]O2peak at 9 km·h (-5.6%; p = 0.02). Maximal isometric strength of knee flexors and extensors did not change. The results suggest a plyometric-agility training program may increase the V[Combining Dot Above]O2peak in female soccer players; however, the effect on RE was equivocal.

Sathish and Senthil Kumar (2012) found out the combined effects of plyometrics and resistance training on selected explosive ability of university volleyball players. For this purpose, forty male volleyball players studying in Prist University Thanjavur District, were selected as subjects at random and they were decided randomly into two groups of twenty each, namely Combined polymeric and Resistance Training Group and Control Group. The training period was limited to twelve weeks and for three days per week. The dependent variables selected for this study were Vertical Jumping Ability. The data obtained from the Experimental groups before and after the experimental period were statistically analyzed with Analysis of covariance (ANCOVA). The level of confidence was fixed at 0.5 levels for all the cases. Vertical Jumping Ability and Horizontal Jumping ability showed significant difference between the groups.

Adibpour et al., (2012) compared the effect of combined exercises (plyometric and weight training) on vertical jump of female basketball players. Out of 35 basketball players who competed in first division league of Tehran clubs, 16 players (age: 20.38±3.7 yr, weight: 65.5±11.5 kg and height: 174.78±6.23 cm)participated voluntarily in this study. They were randomly assigned to two experimental and control groups. The experimental group performed plyometric exercises (which consisted of side hop, lay up jump, depth jump)and weight exercises (which included leg press lying, calf raises, leg press standing) 3 days per week for8 weeks while the control group performed only the vertical jump that was measured with Sargent Jump test. Both groups took part in the pretest and posttest. The accepted level of significant was $p<0.05$. The results indicated the significant effect of combined exercises on vertical jump ($p<0.05$). In addition, the results revealed that the vertical jump of experimental group was significantly greater than control group ($p<0.05$). The results showed that these exercises can also build up foot muscles and increase explosive feet power. Therefore, the application of combined exercises to jumping sports was suggested.

2.4 SUMMARY OF THE RELATED LITERATURE

The related studies proved that several attempts were made researches to ascertain, The effect of different intensity plyometric training, weight training on the skill development of volleyball players. Though several attempts were made there was lack of researches on the effect of cross training, high intensity plyometric training and anaerobic training on selected motor fitness, physiological and skill variables of volleyball players. Hence, researcher made an attempt to find out influence of high intensity plyometric training, anaerobic training, cross training on agility, speed, explosive power, flexibility, coordination , resting pulse rate, respiratory rate, Vo2 max, breath holding time, anaerobic power, set, attack, block, pass, and serve. Based on the experience gained the researcher formulated suitable methodology for this research which is present in Chapter III.