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 literature in any forms the foundation upon which all future work will be built. “The review of literature is generally used as a basis for inductive reasoning for locating and synthesizing all the relevant literature on particular topic”. The research scholar has gone through the available related literature, which are relevant to the present study and have been presented in plyometric training. The literature in any field forms the foundation upon which all future work will be built. If we fail to build upon the foundation of knowledge provided by the review of literature, the researcher might miss some works already done on the same topic. The review of the literatures has been classified under the following headings.

1. Studies on Plyometric Training
2. Studies on Motor Ability Components
3. Studies on Physiological Variables
2.1. STUDIES ON PLYOMETRIC TRAINING

Ebben WP, et al, (2010). This study evaluated the effectiveness of periodized plyometric training for women, and performance is not influenced by the length of post training recovery period. The study evaluated the effectiveness of a periodized plyometric training program and the impact of the duration of the post-training recovery period on countermovement jump performance. Fourteen women subjects participated in a 6-week periodized plyometric training program. Ten women subjects served as non-training controls. All subjects' countermovement jump height, peak power, and body mass were assessed before and 2, 4, 6, 8, and 10 days after training. Kinetic data were obtained via a force platform using the average of 3 repetitions of the countermovement jump for each testing session. Jump height was 25.0% greater (p < or = 0.05) after training with no difference (p > 0.05) between recovery periods of 2, 4, 6, 8, or 10 days, for the training group. Peak power was 11.6-14.3% (p < or = 0.001) greater after training for the training group with no difference (p > 0.05) between recovery periods of 2, 4, 6, 8, or 10 days. Analysis revealed no significant difference (p > 0.05) for jump height or peak power from pre- to post test for the control group. Practitioners should prescribe periodized plyometric programs with decreasing volume and increasing intensity to
improve jump performance without a need for a post-training recovery period.

**Wallace BJ, et al,(2010).** The purpose of this study was to quantify the vertical ground reaction forces (VGRFs) developed during the performance of popular bilateral plyometric movements. Fourteen power-oriented track and field men of collegiate and national level randomly performed 3 trials of 9 different bilateral plyometric exercises in a single testing session. Three depth drop (DD) and 3 depth jump (DJ) conditions from 30, 60, and 90 cm heights (DD30, DD60, and DD90 and DJ30, DJ60, and DJ90) were tested, in addition to vertical jump (VJ), standing long jump (SLJ), and 2 consecutive jump (2CJ) conditions. Peak impact VGRFs were normalized to body weight. Additionally, all conditions were compared against the VJ in an intensity index. The SLJ condition resulted in a significantly higher peak VGRF than the 2CJ condition (p < or = 0.05). 90DD, 90DJ, 60DD, and SLJ had a significantly greater peak VGRF (5.39, 4.93, 4.30, and 4.22 times body weight, respectively) than the VJ condition (3.34 times body weight). The 30DJ condition had an insignificantly smaller peak VGRF (2.78 times body weight) when compared with the VJ. Practitioners may use these findings to more
effectively progress athletes in these movements based on their intensities.

Guadalupe-grau A et al, (2009) conducted a study on the strength training combined with plyometric jumps in adults: sex differences in fat bone axis adaptations. Leptin and osteocalcin play a role in the regulation of the fat bone axis and may be altered by exercise. To determine whether osteocalcin reduces fat mass in humans fed ad libitum and if there is a sex dimorphism in the serum osteocalcin and lepton responses to strength training, we studied 43 male (age 23.9 ± 2.4 yr, mean ±/− SD) and 23 female physical education students (age 23.2 ± 2.7 yr). Subjects were randomly assigned to two groups: training (TG) and control (CG). TG followed a strength combined with plyometric jumps training program during 9 week, whereas the CG did not train. Physical fitness, body composition (Dual-energy X-ray absorptiometry). In the whole group of subjects (prétraining), the serum concentration osteocalcin was positively correlated (r = 0.29-0.42, p < 0.05) with whole body and regional bone mineral content, lean mass, dynamic strength, and serum free testosterone concentration (r=0.32). However, osteocalcin was negatively correlated with leptin concentration (r = 0.37). Fat mass (r = -0.31), and the percent body fat (r = -0.44). Both sexes experienced similar relative improvements in performance,
lean mass (+ 4-5 %), and whole body (+ 0.78 %) and lumbar spine bone mineral content (+ 1.2-2%), with training. Serum osteocalcin concentration was increased after training by 45 and 27% in men and women. Respectively (p < 0.05). Fat mass was not altered by training. Vastus laterals type II MHC compositional at the start of the training program predicted 25% of the osteocalcin increase after training. Serum leptin concentration was reduced either training in women. In summer, while the relative effector’s strength training plus plyometric jumps in performance. Muscle hypertrophy, and osterogenesis are similar in men and women, serum leptin concentration is reduced only in women. The osteocalcin response to strength trainings is in reduced only in women. The osteocalcin response to strength training is, in part, modulated by the muscle phenotype (MHC isoform composition) despite the increase in osteocalcin, fat mass was not reduced.

**Solanikidis K, et al, (2008).** The purpose of the study was to determined the effectives of plyometric, tennis drills and combined on reaction lateral and linear speed, power and strength in novice tennis players Reaction time, first-step quickness, lateral (side steps), and forward speed over short distances are important parameters for tennis performance. The aims of this study were: (i) to diagnose the presence of laterality
in tennis lateral movements and (ii) to compare the effects of plyometric training (PT), tennis-specific drills training (TDT), and combined training (CT) on performance in tennis-specific movements and power/strength of lower limbs. Sixty-four novice tennis players (21.1 +/- 1.3 years) were equally (n = 16) assigned to a control (C), PT, TDT, or CT. Training was performed 3 times/week for 9 weeks. Testing was conducted before and after training for the evaluation of reaction time (single lateral step), 4-m lateral and forward sprints, 12-m forward sprints with and without turn, reactive ability, power, and strength. There was a significant difference in lateral speed (side-steps) between the 2 sides (P < 0.05). PT, TDT, or CT improved the 4m lateral and forward sprints (P < 0.05). PT and CT improved also the reaction time of the "slow" side (P < 0.05), whereas TDT and CT improved the 12-m sprint performances with and without turn (P < 0.05). Power and strength improved in most tests after PT and CT. Lateral and forward sprints were correlated (r = -0.50 to -0.75; P < 0.05) with power/strength. In conclusion, PT improved fitness characteristics that rely more on reactive strength and powerful push-off of legs such as, lateral reaction time, 4-m lateral and forward sprints, drop jump and maximal force. TDT improved all 4-m and 12-m sprint performances, whereas CT appeared to incorporate the advantage of both programs and improved most
tests items. Tennis coaches should be aware that each training regimen may induce more favorable changes to different aspects of fitness, response to strength training is, in part, modulated by the muscle phenotype (MHC isoform composition) despite the increase in osteocalcin, and fat mass was not reduced.

**Villarreal et al, (2008).** Study on compared the low and moderate plyometric training frequency produces greater jumping and sprinting gains compared with high frequency, forty two students were randomly assigned to 1 of 4 groups: control 14 sessions of DJ training and 28 sessions of DJ training. The training protocols included DJ from 3 different heights 20,40 and 60cm. Maximal strength, vertical height in counter movements jumps and DJs and 20m sprint timers tests were carried out before and after 7 weeks of plyometric training. No significant difference was observed among the groups in pre training in any of the variables tested .No significant changes were observed in the control groups in any of the variables tested at any point.. Short-term plyometric training using moderate training frequency and volume of jumps produce similar enhancements in jumping performance, but greater training efficiency compared with high jumping training frequency. In addition, similar enhancements in jumping performance, but greater training frequency. In addition, similar enhancements 20 m
sprint time, jumping contact times and maximal strength were observed in both a moderate and low number of training sessions per week compared with high training frequencies, despite the fact that the average number of jumps accomplished in 7s was 25 and 50% of the that performed in 28s. These observations may have considerable practical relevance for the optimal design of plyometric training program for athletes, given that a moderate volume is more efficient than a higher plyometric training volume.

**Markovic G, et al, (2007)**. Investigated on Effects of sprint and plyometric training on muscle function and athletic performance the purpose of this study was to evaluate the effects of sprint training on muscle function and dynamic 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 for 3 days a week:
SG performed maximal sprints over distances of 10 - 50 M., whereas PG performed bounce-type hurled 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 size ES were moderate high 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 and 7% ES = 0.4), as well as sprint (3.1%; ES = 0.9) and agility (4.3%; ES = 1.1) Performance. We conclude that short term sprint and athletic performance then does conventional plyometric training. This study provides support for the use of sprint training as an applicable training method of improving explosive performance of athletes in general.

**Kotzamanidis, C., (2006).** Examined a study on Effect on plyometric training on running performance and vertical jump in prepubertal boys. The purpose of this study was to investigate the effect of plyometric training on running velocity (RV) and squat jump (SJ) in prepubescent boys. Fifteen boys (11.1 +/- 0.5 years) followed a 10 weeks plyometric program (JUMP group). Another group of 15 boys (10.9 +/- 0.7 years) followed only the
physical education program in primary school and was used as the control group (CONT group). Running distances (0-10M, 10-20 M, and 20-30 M and 0-30m), were selected as testing variables to evaluate the training program. The total number of humps was initially 60 per session, which was gradually increased over a period of 10 weeks to 100 per session. Results revealed significant difference between CONT and JUMP groups in RV and SJ. In JUMP group the velocity for the running distances 0-30,10-20 and 20-30 m increased (P < 0.05), but not for the distance 0-10 m (P >0.05). Additionally, the SJ performance of the JUMP group increased significantly as well (P < 0.05). There was no change in either RV or SJ for the CONT group. These results indicate that plyometric exercise can improve SJ and RV in pre pubertal boys'. More specifically; this program selectively influenced the maximum velocity phase, but not the acceleration phase.

Toumi H, Best et al, (2004). Examined a study on the Effects of eccentric phase velocity of plyometric training on the vertical jump. The aim of the study was to compare the effects of plyometric training performed with rapid (or) slow stretch contractions on jump performance and muscle properties were compared. Thirty males between the ages of 19 and 22 volunteered for the 8-week experiment. Subjects were divided
into the following three groups: training groups (1)(TG1) training group (TG2) and control group (CG, n=6). Each of the 2 experimental groups underwent a unique training regimen. For the first group (TG1, n=12) from a standing position, the subject flexed his knees to a 90 degrees angle with velocity standardized and controlled at 0.4m/s and immediately performed a leg extension as quickly as possible. For the second group (TG2, n=12): from a standing position, the subject flexed his knees to a 90 degrees angles with velocity standardized at 0.2m/s and then performed a leg extension as quickly as possible. Each exercise consisted of six sets of ten repetitions with barbell on the shoulders at 70% of the maximal isometric force (IRM). The 70% load was modified at two weak intervals by evaluating a new 1RM. Exercises were performed four times a week over the eight week period the third group(CG)(n=6)served as control group. Maximal isometric force(MVC), maximal concentric force, squat jump(SJ)and counter movement exercise (CMJ) were performed before and after the training program. Subjects were filmed (100HZ) and each jump was divided into three phases: Eccentric phases (ECG), transition phases (TR) and concentric phases (CON), surface EMG was used to determine the changes in the electromyography (EMG) activity before and after the training program. There was an increase in leg extension force, velocity
and electrical activity for SJ and CMJ for the two training groups (P<0.05). However, TG1 showed a significant advantage in CMJ performance as well as a significant decrease in TR compared to the TG2 (P<0.05). The results of this study show that when plyometric training performed with rapid stretch contraction, the CMJ jump height increase and the TR decrease.

**Turner, Owings and Schwane, (2003).** A study was undertaken to determine whether a 6-week regimen of plyometric training would improve running economy. Eighteen regular but not highly trained distance runners were randomly assigned to experimental and control groups. All subjects continued regular running for 6 weeks; experimental subjects also did polymeric training. Dependent variables measured before and after the 6 weeks period were economy of running on a level of treadmill at 3 velocities [Women: 2.23, 2.68 and 3.13Ms[-1]; men: 2.68, 3.13 and 3.58Ms[-1]; VO (2) max, and indirect indicators of ability of muscles of lower limbs to store and return elastic energy. The last were measurements during jumping tests on an inclined [20 degrees] sled: maximal jump height with (or) without counter movement and efficiencies of series of 40 sub maximal Counter movement and static jumps. The plyometric training improved economy. The vo2 max did not change with training. Plyometric training did not result in
changes in jump height (or) efficiency variables that would have indicated improved ability to store and return elastic energy

**Masamoto et al, (2003).** Conducted a study on the acute effects of plyometric exercise maximum squat performance in trained male athletes. This study examines the acute effects of plyometric exercise on one repetition maximum(RM) squat performance in trained male athletes Twelve men mean age +/-SD:20.5 +/-1.4years) volunteered to participated in 3 testing sessions separated by at least 6 days of rest. During each testing sessions the 1 Rm was assessed on back squat exercise. Before all 3 trials subjects warmed up on stationary cycle for 5 minutes, and performed static stretching. Subjects then performed 5 sub maximal sets of 1-8 repetitions before attempting a 1Rm lift. Subjects rested for at least 4 minutes between 1Rm trials. During the first testing session (T1) subjects performed a series of sets with increasing load until their 1Rm was determined. During the second and third testing sessions subjects performed in counter balanced order either in 3 double-leg tuck jumps (TJ) or 2 depths jumps (DJ) 30 seconds before each 1 Rm attempt. The average 1Rm lifts after T1 and testing sessions with TJ and DJ were 139.6+/-29.3kg, 140.5+/-25.6kg and 144.5+/-30.2kg respectively. (T1<DJ; P<0.05) These
data suggest that DJ performed before 1Rm testing may enhance squat performance in trained male athletes.

Swanik et al, (2002). The purpose of this study is to find the effect of plyometric training of the shoulder internal rotators on proprioception kinesthesia and selected muscle performance characteristics in female swimmers. For this, 24 female divisions one swimmer were evaluated before and after a 6-week plyometric training program. Proprioception and kinesthesia were assessed for internal and external rotation at 0 degrees, 75 degrees, and 90% of the subjects maximum external rotation. The biodex II was used to assess strength characteristics at 60 degree/s, 240 degree/s and 450 degree/s. Plyometric training sessions (2 times/week) involved 3 sets of 15 repetitions with a trampoline, weighted balls and elastic tubing. A 2-way analysis of variance revealed significant improvement (P<0.05) in proprioception at 0 degrees moving into both external rotation, as well as 75 degrees and 90% moving into both internal and external rotation. Kinesthesia demonstrated significant improvement for all test conditions after plyometric training. Significant gains in selected muscles performance characteristics included time to peak torque (60 degree/s and 240 degree/s), amortization time (450 degree/s) and torque decrement (240 degree/s). This study suggests that plyometric activities may
facilitate neural adaptations that enhance proprioception, kinesthesia and muscle performance characteristics. Significant neuromuscular benefits may be attained if they are implemented earlier into shoulder rehabilitation programs.

2.2. STUDY ON MOTOR ABILITY COMPONENTS

Chatzinikolaou A, et al., (2010). The study evaluated on the Time course of changes in performance and inflammatory responses after acute plyometric exercise. The objectives of the present investigation were to study the inflammatory and performance responses after an acute bout of intense plyometric exercise during a prolonged recovery period. Participants were randomly assigned to either an experimental group (P, n = 12) that performed intense plyometric exercises or a control group (C, n = 12) that rested. The delayed onset of muscle soreness (DOMS), knee range of motion (KROM), creatine kinase (CK) and lactate dehydrogenases (LDH) activities, white blood cell count, C reactive protein (CRP), uric acid (UA), cortical, testosterone, IL-6, IL-1b strength (isometric and isokinetic), and countermovement (CMJ) and static (SJ) jumping performance were measured at rest, immediately post exercise and at 24, 48, 72, 96, and 120 hours of recovery. Lactate was measured at rest and post exercise. Strength remained unchanged throughout recovery.
but CMJ and SJ declined (p < 0.05) by 8-20%. P induced a marked rise in DOMS, CK, and LDH (peaked 24-48 hours post exercise) and a KROM decline. An acute-phase inflammatory response consisting of leukocytes (post exercise and at 24 hours), an IL-6, IL-1b, CRP, and cortical elevation (during the first 24 hours of recovery) and a delayed increase of UA (peaked at 48 hours) and testosterone (peaked at 72 hours) was observed in P. The results of this investigation indicate that performing an acute bout of intense plyometric exercise may induce short-term muscle damage and marked but transient inflammatory responses. Jumping performance seems to deteriorate for as long as 72 hours post exercise, whereas strength appears to remain unchanged. The acute-phase inflammatory response after a plyometric exercise protocol appears to follow the same pattern as in other exercise models. These results clearly indicate the need of sufficient recovery between successive plyometric exercises training sessions. Improving repeated sprint ability in young elite soccer players: repeated shuttle sprints vs. explosive strength training

The purpose of this investigation was to examine the effect of a standard plyometric training protocol with or without added load in improving vertical jumping ability in male basketball players.
Twenty-seven players were randomly assigned to 3 groups: a control group (no plyometric training), plyometric training group (PG), and loaded plyometric group (LPG, weighted vests 10-11% body mass). Before and after the 10-week training program, all the players were tested for the 5-jump test (5JT), the squat jump (SJ), and the countermovement jump (CMJ). The PG and LPG groups performed 2 and 3 training sessions per week, during the first 3 and the last 7 weeks, respectively. The results showed that SJ, CMJ, and 5JT were significantly improved only in the PG and LPG groups. The best effects for jumps were observed in LPG (p < 0.01), which showed significantly higher gains than the PG (p < 0.05). In conclusion, it appears that loads added to standard plyometric training program may result in greater vertical and horizontal-jump performances in basketball players.

**Santos EJ, Janeira MA., et al, (2010).** The aim of the study was conducted on the Effects of Plyometric Training Followed by Detraining and Reduced Training Periods on Explosive Strength in Adolescent Male Basketball Players. The effects of plyometric training followed by detraining and reduced training periods on explosive strength in adolescent male basketball players. The aims of this study were to determine the effects of (a) plyometric training on explosive strength indicators in adolescent male basketball players and (b) detraining and
reduced training on previously achieved explosive strength gains. Two groups were formed: an experimental and a control group. The former was submitted to a 10-week in-season plyometric training program, twice weekly, along with regular basketball practice. Simultaneously, the control group participated in regular basketball practice only. At the end of this period, the experimental group was subdivided into 2 groups: a reduced training group and a detraining group. All participants were assessed on squat jump, countermovement jump, Abalakov test, depth jump, mechanical power, and medicine ball throw at the beginning and at the end of the 10-week in-season plyometric training and on weeks 4, 8, 12, and 16 of the in-season detraining and reduced training periods. In the first phase of the study, the experimental group significantly increased all the assessed indicators (p < 0.05). In the following phase and in general all the groups maintained the previously achieved results. In conclusion, plyometric training showed positive effects on upper- and lower-body explosive strength in adolescent male basketball players. Moreover, we can state that both detraining and a reduced training program indistinctly contribute to maintenance of strength levels. These results highlight the unique power that basketball-specific training
seems to have on the sustainability and maintenance of sport performance

**Trzaskoma L, et al, (2010).** Conducted a study on the effect of a short-term combined conditioning training for the development of leg strength and power. The aim of the study was to compare the effect of combined weight and pendulum training exercises with those isolated ones on muscle strength and vertical jump performance. A total of 38 young active men were divided into 4 groups performing different combinations of strength and power training and measured directly and 2 weeks after the training program. Weight training and pendulum swing exercises, involving lower body during dynamic bounces, were used. Results of 1 repetition maximum (1RM) in full squat and squat jump with the barbell, maximal force measured during countermovement jump (CMJ), and hip and knee flexor and extensor isometric strength were analyzed. Significant differences (p <0.05) in strength test (1RM squat, hip and knee flexor and extensor strength) were found when performing weight training (1RM-10.2%; maximal torques-23.2%). Positive significant increase (p <0.05) in all strength and power parameters (maximal torques-from 2, 468.9 +/- 387.4 to 2, 712.4 +/- 501.6 Nxm; 1RM squat-from 93.9 +/- 15.0 to 111.4 +/- 15.6 kg; CMJ power-from 3, 050.7 +/- 478.5 to 3, 419.8 +/-
506.6 W; CMJ jump height—from 48.8 +/- 4.1 to 53.4 +/- 3.0 cm) after the training program was found when combined training was used. Seated safety position during the pendulum swing is responsible for significant training effect with reduced loads. Plyometric pendulum swing training combined with traditional training can be an alternative, effective method to increase muscle strength and power during short pre or in-season mesocycles.

Wu YK et al, (2010). The present study has demonstrated briefly Relationships between three potentiation effects of plyometric training and performance. This study measured the potentiation effects of plyometric training [normalized electromyography (EMG) in triceps surae, stiffness and elastic energy utilization of the Achilles tendon] and investigated the correlations between these effects and performances [voluntary electromechanical delay (EMD) and jump height]. Twenty-one subjects were randomly assigned either to the control group (10 subjects: age 22.3 +/- 1.6 years) or to a training group (11 subjects: age 22.1 +/- 1.6 years) that performed 8 weeks of plyometric training. Results: As compared with the performances before training, normalized EMG in the soleus were significantly (P<0.001) increased after 4 and 8 weeks of training. Tendon stiffness, elastic energy storage, release and jump height
determined after training were significantly increased (P<0.05), with a concomitantly reduced voluntary EMD (P=0.01). These variables also showed significant differences vs the control group (all P<0.05). The other variables remained unchanged. Correlations were observed between tendon stiffness and either voluntary EMD (r=-0.77, P=0.014) or jump height (r=0.54, P=0.031). Conclusions: Plyometric training specifically potentiated the normalized EMG, tendon stiffness and elastic energy utilization in the myotendinous complex of the triceps surae. Although these changes are possibly essential determinants, only increases of tendon stiffness were observed to correlate with performance improvements.

**Drinkwater EJ, et al, (2009).** The present study has demonstrated that Effect of an acute bout of plyometric exercise on neuromuscular fatigue and recovery in recreational athletes. Although plyometric training is widely used by sports coaches as a method of improving explosive power in athletes, many prescribe volumes in excess of the National Strength and Conditioning Association recommendations. The purpose of this study was to assess voluntary and evoked muscle characteristics to assess the neuromuscular impact of a high-volume about of plyometric exercise that was non-exhaustive. Ten athletes who did not have plyometric training experience were in their
competitive season for club-level sport volunteered for the study. After at least 2 days without high-intensity activity, subjects were assessed on maximal twitch torque, time to peak torque, rate of twitch torque development, twitch half-relaxation time, rate of twitch relaxation, and voluntary activation by the interpolated twitch technique before, immediately after, and 2 hours after a high-volume plyometric training program (212 ground contacts). Data were analyzed by repeated-measures analysis of variance and described as mean +/- SD and Cohen d. Statistically significant decrements appeared immediately after the training protocol in the total torque generated by maximal voluntary contractions (p < 0.05, d = -0.51) and twitch (p < 0.01, d = -0.92), rate of twitch torque development (p < 0.01, d = -0.77), and rate of relaxation (p < 0.01, d = -0.73). However, we did not observe any differences that remained statistically different after 2 hours. There were no significant differences observed at any time point in time to peak twitch, half-relaxation time, or voluntary activation. We conclude that high-volume plyometric training results primarily in peripheral fatigue that substantially impairs force and rate of force development. We recommend that coaches carefully monitor the volume of plyometric training sessions to avoid neuromuscular impairments that can result in sub optimal training.
Meylan C., et al, (2009). Conducted study on Effects of in-season plyometric training within soccer practice on explosive actions of young players. In soccer, explosive actions such as jumping, sprinting, and changes of direction are essential to optimal performance not only in adults, but also in children's games. The purpose of the present investigation was to determine the influence of short-term plyometric training within regular soccer practice on explosive actions of early pubertal soccer players during the in-season. 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 program (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 was recorded for the CG. The current study demonstrated that a plyometric program within regular soccer practice improved explosive actions of young players compared to conventional soccer training only. Therefore, the short-term plyometric program 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.

**Sedano Campo S., et al, (2009).** Conducted a study on effects of lower-limb plyometric training on body composition, explosive strength, and kicking speed in female soccer players. The aim of the present study was to examine how explosive strength, kicking speed, and body composition are affected by a 12-week plyometric training program in elite female soccer players. The hypothesis was that this program would increase the jumping ability and kicking speed and that these gains could be maintained by means of regular soccer training only. Twenty adult female players were divided into 2 groups: control group (CG, n = 10; age 23.0 +/- 3.2 yr) and plyometric group (PG, n = 10; age 22.8 +/- 2.1 yr). The intervention was carried out during the second part of the competitive season. Both groups performed technical and tactical training exercises and matches
together. However, the CG followed the regular soccer physical conditioning program, which was replaced by a plyometric program for PG. Neither CG nor PG performed weight training. Plyometric training took place 3 days a week for 12 weeks including jumps over hurdles, drop jumps (DJ) in stands, or horizontal jumps. Body mass, body composition, countermovement jump height, DJ height, and kicking speed were measured on 4 separate occasions. The PG demonstrated significant increases \( p < 0.05 \) in jumping ability after 6 weeks of training and in kicking speed after 12 weeks. There were no significant times x group interaction effects for body composition. It could be concluded that a 12-week plyometric program can improve explosive strength in female soccer players and that these improvements can be transferred to soccer kick performance in terms of ball speed. However, players need time to transfer these improvements in strength to the specific task. Regular soccer training can maintain the improvements from a plyometric training program for several weeks.

**Thomas et al, (2009).** Conducted a study on compare the effect of two plyometric training techniques on muscular power and agility in youth soccer players. Thirty males from as semiprofessional football club’s academy were randomly assigned to 6 weeks of depth jump (DJ) or counter movement
jump (CMJ) training twice weekly. Participants in the DJ group performed drop jump with instructions to minimize ground contact time while maximizing 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 treatments groups (p=0.05) the study concludes that both depth jump and counter movement jump (CMJ) plyometric are worth while training activities for improving power and agility in youth soccer players.

**Castagna C., et al, (2008).** Conducted a study on effect of recovery mode on repeated sprint ability in young basketball players. The aim of this study was to examine the effect of recovery mode on repeated sprint ability in young basketball players. Sixteen basketball players (age, 16.8 +/- 1.2 years; height, 181.3 +/- 5.7 cm; body mass, 73 +/- 10 kg; vo2max 59.5 +/- 7.9 ml x kg(-1) x min(-1)) performed in random order over 2 separate occasions 2 repeated sprint ability protocols consisting of 10x30-m shuttle run sprints with 30 seconds of passive or active (running at 50% of maximal aerobic speed) recovery. Results showed that fatigue index (FI) during the active protocol
was significantly greater than in the passive condition (5.05 +/- 2.4, and 3.39 +/- 2.3, respectively, p<0.001). No significant association was found between VO$_2$ peak and FI and Sprint total time (TT) in either repeated sprint protocols. Blood lactate concentration at 3 minutes post exercise was not significantly different between the 2 recovery conditions. The results of this study show that during repeated sprinting, passive recovery enabled better performance, reducing fatigue. Consequently, the use of passive recovery is advisable during competition in order to limit fatigue as a consequence of repeated high intensity exercise.

De Villarreal ES., et al, (2008). Conducted a study on Low and moderate plyometric training frequency produces greater jumping and sprinting gains compared with high frequency. The purpose of this study was to examine the effect of 3 different plyometric training frequencies (e.g., 1 day per week, 2 days per week, 4 days per week) associated with 3 different plyometric training volumes on maximal strength, vertical jump performance, and sprinting ability. Forty-two students were randomly assigned to 1 of 4 groups: control (n = 10, 7 sessions of drop jump (DJ) training, 1 day per week, 420 DJs), 14 sessions of DJ training (n = 12, 2 days per week, 840 DJs), and 28 sessions of DJ training (n = 9, 4 days per week, 1680 DJs).
The training protocols included DJ from 3 different heights 20, 40, and 60 cm. Maximal strength (1 repetition maximum [1RM] and maximal isometric strength), vertical height in countermovement jumps and DJs, and 20-m sprint time tests were carried out before and after 7 weeks of plyometric training. No significant difference was observed among the groups in pre-training in any of the variables tested. No significant changes were observed in the control group in any of the variables tested at any point. Short-term plyometric training using moderate training frequency and volume of jumps (2 days per week, 840 jumps) produces similar enhancements in jumping performance, but greater training efficiency (approximately 12% and 0.014% per jump) compared with high jumping (4 days per week, 1680 jumps) training frequency (approximately 18% and 0.011% per jump). In addition, similar enhancements in 20-m-sprint time, jumping contact times and maximal strength were observed in both a moderate and a low number of training sessions per week compared with high training frequencies, despite the fact that the average number of jumps accomplished in 7S (420 jumps) and 14S (840 jumps) was 25 and 50% of that performed in 28S (1680 jumps). These observations may have considerable practical relevance for the optimal design of plyometric training
programs for athletes, given that a moderate volume is more efficient than a higher plyometric training volume.

Impellizzeri FM, et al., (2008). was conducted a study on Effect of plyometric training on sand versus grass on muscle soreness and jumping and sprinting ability in soccer players. The lower impact on the musculoskeletal system induced by plyometric exercise on sand compared to a firm surface might be useful to reduce the stress of intensified training periods or during rehabilitation from injury. The aim of this study was to compare the effects of plyometric training on sand versus a grass surface on muscle soreness, vertical jump height and sprinting ability. Parallel two-group, randomized, longitudinal (pretest-post-test) study. After random allocation, 18 soccer players completed 4 weeks of plyometric training on grass (grass group) and 19 players on sand (sand group). Before and after plyometric training, 10 m and 20 m sprint time, squat jump (SJ), countermovement jump (CMJ), and eccentric utilization ratio (CMJ/SJ) were determined. Muscle soreness was measured using a Likert scale. No training surface x time interactions were found for sprint time (p>0.87), whereas a trend was found for SJ (p = 0.08), with both groups showing similar improvements (p<0.001). On the other hand, the grass group improved their CMJ (p = 0.033) and CMJ/SJ (p = 0.005) significantly (p<0.001)
more than players in the sand group. In contrast, players in the sand group experienced less muscle soreness than those in the grass group (p<0.001). Plyometric training on sand improved both jumping and sprinting ability and induced less muscle soreness. A grass surface seems to be superior in enhancing CMJ performance while the sand surface showed a greater improvement in SJ. Therefore, plyometric training on different surfaces may be associated with different training-induced effects on some neuromuscular factors related to the efficiency of the stretch-shortening cycle.

Marques MC, et al., (2008). Conducted a study on changes in strength and power performance in elite senior female professional volleyball players during the in-season: a case study. It is often recommended that in-season training programs aim to maintain muscular strength and power developed during the off-season. However, improvements in performance may be possible with a well-designed training regimen. The purpose of this case report is to describe the changes in physical performance after an in-season training regimen in professional female volleyball players in order to determine whether muscular strength and power might be improved. Apart from normal practice sessions, 10 elite female volleyball players completed 2 training sessions per week, which
included both resistance training and plyometric exercises. Over the 12-week season, the athletes performed 3-4 sets of 3-8 repetitions for resistance and plyometric exercises during each training session. All sessions were supervised by one of the investigators as well as by the team head coach. Muscular strength and power were assessed before and after the 12-week training program using 4 repetition maximum bench press and parallel squat tests, an overhead medicine ball throw (BTd), as well as unloaded and loaded countermovement jumps (CMJs). Strength improved by 15% and 11.5% in the bench press and parallel squat, respectively (p < 0.0001). Distance in the BTd improved by 11.8% (p < 0.0001), whereas unloaded and loaded CMJ height increased between 3.8 and 11.2%. The current findings suggest that elite female volleyball players can improve strength and power during the competition season by implementing a well-designed training program that includes both resistance and plyometric exercises.

Perez-Gomez J, et al, (2008). Conducted a study on effects of weight lifting training combined with plyometric exercises on physical fitness, body composition, and knee extension velocity during kicking in football. The effects of a training program consisting of weight lifting combined with plyometric exercises on kicking performance, myosin heavy-
chain composition (vastus lateralis), physical fitness, and body composition (using dual-energy X-ray absorptiometry (DXA)) was examined in 37 male physical education students divided randomly into a training group (TG: 16 subjects) and a control group (CG: 21 subjects). The TG followed 6 weeks of combined weight lifting and plyometric exercises. In all subjects, tests were performed to measure their maximal angular speed of the knee during in-step kicks on a stationary ball. Additional tests for muscle power (vertical jump), running speed (30 m running test), anaerobic capacity (Wingate and 300 m running tests), and aerobic power (20 m shuttle run tests) were also performed. Training resulted in muscle hypertrophy (+4.3%), increased peak angular velocity of the knee during kicking (+13.6%), increased percentage of myosin heavy-chain (MHC) type IIa (+8.4%), increased 1 repetition maximum (1 RM) of inclined leg press (ILP) (+61.4%), leg extension (LE) (+20.2%), leg curl (+15.9%), and half squat (HQ) (+45.1%), and enhanced performance in vertical jump (all p < or = 0.05). In contrast, MHC type I was reduced (-5.2%, p < or = 0.05) after training. In the control group, these variables remained unchanged. In conclusion, 6 weeks of strength training combining weight lifting and plyometric exercises results in significant improvement of kicking performance, as well as other physical capacities related to success in football (soccer).
Ronnestad BR., et al, (2008). Compared the effects of combined strength and plyometric training with strength training alone on power-related measurements in professional soccer players. Subjects in the intervention team were randomly divided into 2 groups. Group ST (n = 6) performed heavy strength training twice a week for 7 weeks in addition to 6 to 8 soccer sessions a week. Group ST+P (n = 8) performed a plyometric training program in addition to the same training as the ST group. The control group (n = 7) performed 6 to 8 soccer sessions a week. Pretests and posttests 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. There were no significant differences between the ST+P group and ST group. Thus, the groups were pooled into 1 intervention group. The intervention group significantly improved in all measurements except CMJ, while the control group showed significant improvements only in PP20. There was a significant difference in relative improvement between the intervention group and control group in 1RM half squat, 4BT, and SJ. However, a significant difference between groups was not observed in PP20, PP35, sprint acceleration,
peak sprinting velocity, and total time on 40-m sprint. The results suggest that there are 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, heavy strength training leads to significant gains in strength and power-related measurements in professional soccer players.

Sáez, DeVillarreal E., et al, (2008). conducted a study on effect of plyometric training on chair-rise, jumping and sprinting performance in three age groups of women. The main purpose of this study was to investigate the influence of 8-wk periodized plyometric training (PT) on chair-rise, jumping and sprinting performance in three groups of women of different age (40-50; 50-60; 60-70 years). This study involved a group of 55 women between the ages of 40 and 70 with no PT experience participating in a gymnastic program and recreational activity that did not involve jumping and who had participated since five years. All tests to determine the values of strength endurance, vertical jumping performance (VJP) and velocity were carried out before (PRE), after (POST) and following 8 weeks of rest (DETRAINING) of the 8 weeks of PT. The performance tests were completed in 3 days. The primary finding of this investigation
indicates that low impact PT using moderate volume of jumps produced similar enhancements in the three age groups of women in jumping and chair-rise performance (30 CST) (ranging 15-24 %). There were no enhancements in 10 m-sprint time in any of the age groups. In addition, 8 weeks of detraining following an 8 week PT program resulted in similar decreases in chair-rise and jumping performance in all training groups, whereas no further changes were observed in 10-m sprint time. The low impact PT proposed appears to be an optimal stimulus for improving VJP and 30 CST during short-term training periods in untrained middle-aged and elderly women.

Vescovi JD., et al, (2008). Compared the effort of a plyometric program on vertical landing force and jumping performance in college women. Subjects were assigned to one of the three groups; a experimental group I (E.G-I), experimental group –II (E.G.-II) and control group (CG). The EG-I, EG-II groups participated in two packages of plyometric training in 50 minutes session for 6 weeks and 60 minute. No specific training is given for control group. The E.G –I included a warm ups, 30-35 min, and a 5 –min cool down. The E.G.- I I included a 5-7 min warm up 35- 40 min and a 5-7 min cool down’ comparisons were, made using Mann- Whitney u test. Results showed in the intervention group (-222.8 +/- 610.9 N), but was
not statistically different (P= 0.122); compared to the change observed in the control group (54.6+/−257.6N) there was no difference in the absolute change values between groups for counter movement jump height (1.0+/−2.8 cm vs. −0.2 +/−1.5 cm, p=0.696). it was concluded , although not statistically significant, the mean absolute reduction in vertical ground reaction force in the training group is clinically meaning full. Eight of the 10 women in the training group reduced vertical ground reaction force by 17.18 %: however, improvements in jumping performance were not absorbed. This indicates that programs aimed at enhancing performance must be designed differently from those aimed at reducing landing forces in recreationally athletic women.

**Avery faigenbaum (2007).** Conducted a study on compare the effect of a six –week training period of combined plyometric and resistance training (or) resistance training on fitness performance in boys, (They aged ranged from 12 –15 yrs). The resistance-training group performed static stretching exercises followed by resistance training whereas the plyometric and resistance group performed plyometric exercises followed by the same resistance training programme .The training duration per session for both group was 90 min .At baseline after training all participants were tested on the vertical jump. Long jump
medicine ball toss, 9.1m sprint, pro agility, shuttle run and flexibility. The PRT group made significantly (p<0.05) greater improvements than RT in long Jump (10.8cm vs. 2.2cm), medicine ball toss (39.1 cm vs. 17.7cm) and pro agility, shuttle run time (-0.23sec vs. –0.02 sec) following training. These findings suggest that the addition plyometric training to a résistance training program may be more beneficial than resistance training and static stretching for enhancing selected measures of upper and lower body power in boys.

**Castagna C., et al., (2007).** conducted a study on Relation between maximal aerobic power and the ability to repeat sprints in young basketball players. The aim of this study was to examine the effects of maximal aerobic power (V(-)O2 max peak) level on the ability to repeat sprints (calculated as performance decrement and total sprinting time) in young basketball players. Subjects were 18 junior, well-trained basketball players (age, 16.8 +/- 1.2 years; height, 181.3 +/- 5.7 cm; body mass, 73 +/- 10 kg; V(-)O2 max peak, 59.6. +/- 6.9 ml x kg (-1) x min (-1)). Match analysis and time – motion analysis of competitive basketball games was used to devise a basketball – specific repeated – sprint ability protocol consisting of ten 15-m shuttle run sprints with 30 s of passive recovery. Pre, post, and post plus 3-minute blood lactate concentrations were 2.5 +/- 0.7,
No significant correlations were found between V(.-)O2max peak and either FI or total sprint time. A negative correlation (r=-0.75, p=0.01) was found between first-sprint time and FI. The results of this study showed that V(.-)O2 max peak is not a predictor of repeated sprint ability in young basketball players. The high blood lactate concentrations found at the end of the repeated – sprint ability protocol suggests its use for building lactate tolerance in conditioned basketball players.

Luebbers PE., et al, (2007). Have demonstrated briefly Kinematic responses to plyometric exercises conducted on compliant and noncompliant surfaces. Jumping is an important performance component of many sporting activities. A number of training modalities have been used to enhance jumping performance including plyometrics. The positive effects of plyometric training on jumping performance are a function of the stretch-shortening cycle phenomenon. However, there has been little research on the effects of the surface on jumping performance. This study examined the effects of performing 2 different plyometric exercises, depth jump (DJ) and counter movement jump (CMJ), on noncompliant (ground) and compliant (mini-trampoline) surfaces. Male participants (N = 20; age = 21.8
randomly performed 10 CMJ and 10 DJ on compliant and noncompliant surfaces. Kinematic data were determined via 2-dimensional high-speed video. There were significant (p < 0.05) differences in DJ and CMJ joint and segment range of movement for ankle, knee, hip and trunk, indicating less crouch when the participants performed plyometric exercises on the compliant surface.

Markovic G., (2007). Conducted on Does plyometric training improve vertical jump height? A meta-analytical review. The aim of this study was to determine the precise effect of plyometric training (PT) on vertical jump height in healthy individuals. Meta-analyses of randomized and non-randomized controlled trials that evaluated the effect of PT on four typical vertical jump height tests were carried out: squat jump (SJ); countermovement jump (CMJ); countermovement jump with the arm swing (CMJA); and drop jump (DJ). Studies were identified by computerized and manual searches of the literature. Data on changes in jump height for the plyometric and control groups were extracted and statistically pooled in a meta-analysis, separately for each type of jump. A total of 26 studies yielding 13 data points for SJ, 19 data points for CMJ, 14 data points for CMJA and 7 data points for DJ met the initial inclusion criteria.
The pooled estimate of the effect of PT on vertical jump height was 4.7% (95% CI 1.8 to 7.6%), 8.7% (95% CI 7.0 to 10.4%), 7.5% (95% CI 4.2 to 10.8%) and 4.7% (95% CI 0.8 to 8.6%) for the SJ, CMJ, CMJA and DJ, respectively. When expressed in standardized units (i.e., effect sizes), the effect of PT on vertical jump height was 0.44 (95% CI 0.15 to 0.72), 0.88 (95% CI 0.64 to 1.11), 0.74 (95% CI 0.47 to 1.02) and 0.62 (95% CI 0.18 to 1.05) for the SJ, CMJ, CMJA and DJ, respectively. PT provides a statistically significant and practically relevant improvement in vertical jump height with the mean effect ranging from 4.7% (SJ and DJ), over 7.5% (CMJA) to 8.7% (CMJ). These results justify the application of PT for the purpose of development of vertical jump performance in healthy individuals.

_Ratamess NA., et al, (2007)_ conducted a study on effects of ten weeks of resistance and combined plyometric/sprint training with the Meridian Elite athletic shoe on muscular performance in women. The purpose of this investigation was to examine the combined effects of resistance and sprint/plyometric training with or without the Meridian Elite athletic shoe on muscular performance in women. Fourteen resistance-trained women were randomly assigned to one of 2 training groups: (a) an athletic shoe (N = 6) (AS) group or (b) the Meridian Elyte (N = 8) (MS) group. Training was performed for 10
weeks and consisted of resistance training for 2 days per week and 2 days per week of sprint/plyometric training. Linear periodized resistance training consisted of 5 exercises per workout (4 lower body, 1 upper body) for 3 sets of 3-12 repetition maximum (RM). Sprint/plyometric training consisted of 5-7 exercises per workout (4-5 plyometric exercises, 40- and 60-yd sprints) for 3-6 sets with gradually increasing volume (8 weeks) followed by a 2-week taper phase. Assessments for 1RM squat and bench press, vertical jump, broad jump, sprint speed, and body composition were performed before and following the 10-week training period. Significant increases were observed in both AS and MS groups in 1RM squat (12.0 vs. 14.6 kg), bench press (6.8 vs. 7.4 kg), vertical jump height (3.3 vs. 2.3 cm), and broad jump (17.8 vs. 15.2 cm). Similar decreases in peak 20-, 40-, and 60-m sprint times were observed in both groups (20 m: 0.14 vs. 0.11 seconds; 40 m: 0.29 vs. 0.34 seconds; 60 m: 0.45 vs. 0.46 seconds in AS and MS groups, respectively). However, when sprint endurance (the difference between the fastest and slowest sprint trials) was analyzed, there was a significantly greater improvement at 60 m in the MS group. These results indicated that similar improvements in peak sprint speed and jumping ability were observed following 10 weeks of training with either shoe. However, high-intensity sprint endurance at 60 m
increased to a greater extent during training with the Meridian Elyte athletic shoe.

**Stemm JD., et al, (2007).** investigated the difference of land- and aquatic-based plyometric training on vertical jump performance. Plyometric training is a popular method by which athletes may increase power and explosiveness. However, plyometric training is considered a highly intense and potentially damaging activity particularly if practiced by the novice individual or if overdone. The purpose of this study was to compare vertical jump performance after land- and aquatic-based plyometric training. A convenience sample of 21 active, college-age (24 +/- 2.5 years) men were randomly assigned to 1 of 3 groups: group I, aquatic; group II, land; and group III, control. Training for the AQ and LN groups consisted of a 10-minute warm-up followed by 3 sets of 15 squat jumps, side hops, and knee-tuck jumps separated by 1-minute rests. The aquatic group performed the exercises in knee-level water adjusted to parallel the axis of the knee joint (+1 in.). The land group performed identical plyometric exercises on land. The control group engaged in no training. Participants trained twice a week for 6 weeks, and all training sessions were moniitored. Pre- and post-test data were collected on maximum vertical jump height. A 2x3 analysis of variance with repeated measures was
used to compare vertical jump height among the 3 groups. Results suggested that the aquatic- and land-based groups significantly (p < 0.05) outperformed the control group in the vertical jump. No significant difference was found in vertical jump performance between the aquatic- and land-based groups. It was concluded that aquatic training resulted in similar training effects as land-based training, with a possible reduction in stress due to the reduction of impact afforded by the buoyancy and resistance of the water upon landing.

Herrero J.A., et al, (2006). Conducted a study on electromyostimulation and plyometric training effects on jumping and sprint time. This study compared the effects of four week training periods of electromyostimulation (EMS), plyometric training (P), or combined EMS and P training of the knee extends or muscles on 20 M sprint time (ST), jumping ability (squat jump) (S J) and countermovement hump (CmJ), maximal isometric strength (MVC), and muscle cross sectional area (CSA), forty subjects were randomly assigned to one of the four treatment groups: electromyostimulation (EG), plyometric (PG), combined EMG, and P (EPG), that took place 4 times per week, and a control group (CG), subjects were tested before and after the training program, as well as once more after 2 wk of detraining. A significant improvement (P <0.05) in ST was
observed after training (2.4%) in EG while a significant slowing (P<0.05 was obverted –2.3%) in EPG. significant increases in EPG (P<0.05) were observed in SJ (7.5%) and CMJ (7.3%) after training, while no significant changes in both humps were observed after training and detraining for EG. a significant increase (P <0.05) in MVC was observed after training (9.1%) and after detraining (8.1%) in EG. A significant increase (p< 0.05) in MVC was observed after training (16.3% ) in EPG. A significant increase (p < 0.05) in CSA was observed after training in EG (9.0%) and in EPG (7.1%) .EMS combined with plyometric training increased the humping height and sprint run in physically active men. In addition, DMS alone or EMS combined with plyometric training leads to increase maximal Strength and to some hypertrophy of trained muscles. However, EMS training alone did not result in any improvement in jumping explosive strength development or even interfered in sprint run.

2.3. STUDIES ON PHYSIOLOGICAL VARIABLES

Brown GA., et al, (2010). conducted a study on Oxygen consumption, heart rate, and blood lactate responses to an acute bout of plyometric depth jumps in college-aged men and women. Although plyometrics are widely used in athletic conditioning, the acute physiologic responses to plyometrics have not been
described. The purpose of this study was to investigate the oxygen consumption, heart rate, and blood lactate responses to a single session of plyometric depth jumps. Twenty recreationally trained college-aged subjects (10 men, 10 women) participated in a single session of 8 sets of 10 box depth jumps from a height of 0.8 m with 3 minutes of passive recovery between each set. Plyometric depth jumping elicited 82.5 +/- 3.1% and 77.8 +/- 3.1% of the measured maximal oxygen consumption (O2max) for women and men, respectively, with no difference in oxygen consumption in ml/kg/min or percent O2max between sexes or sets. Heart rate significantly increased (p < 0.05) from 68.1 +/- 2.9 beatsxmin-1 at rest to 169.6 +/- 1.2 beatsxmin-1 during depth jumping. Sets 5 to 8 elicited a higher (p < 0.05) heart rate (173.3 +/- 1.3 beatsxmin-1) than sets 1 to 4 (164.6 +/- 1.8 beatsxmin-1). Women exhibited a higher heart rate (p < 0.05) during sets 1 and 2 (169.9 +/- 2.8 beatsxmin-1) than men (150.7 +/- 4.4 beatsxmin-1). The blood lactate concentrations were significantly (p < 0.05) increased above resting throughout all sets (1.0 +/- 0.2 mmolxL-1 compared with 2.9 +/- 0.1 mmolxL-1), with no differences between sexes or sets. Plyometric depth jumping significantly increased oxygen consumption, heart rate, and blood lactate in both men and women, but no significant difference was found between the sexes. Plyometric
depth jumping from a height of 0.8 m has similar energy system requirements to what Wilmore and Costill termed "Aerobic Power" training, which should enhance O2max, lactate tolerance, oxidative enzymes, and lactate threshold.

**Chtara M., et al, (2008).** conducted a study on Effect of concurrent endurance and circuit resistance training sequence on muscular strength and power development. The purpose of this study was to examine the influence of the sequence order of high intensity endurance training and circuit training on changes in muscular strength and anaerobic power. Forty eight physical education students (ages,21.4 +/-1.3 years) were assigned to w 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 d 5 repetition run at ate the velocity associated with Vo2 max (Vo2 max) for duration equal to 50 % of the time to exhaustion at vo2 max; recovery was for an equal period at 60 %^ vo2 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 jumps 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 (0 < 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 explosives 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.

**Saunders et al, (2008).** Compared short-term plyometric training improves running economy highly trained middle and long distance runners. Fifteen highly trained distance runners VO2 max (71.1 +/- 6.0ml min. (-1) kg (-1), mean +/- SD) were randomly assigned to a plyometric training (ply; n=7) or control (con; n=8) groups. In addition to their normal training, the ply group undertook 3 x 30 minutes ply sessions per week for 9 weeks, running economy (RE) was assessed during 3 x 4 minutes treadmill runs (14, 16 and 18 km .h(-1)), followed by an
incremental test to measure VO2 max. Muscle power characteristics were assessed on a portable unidirectional ground reaction force plate, compared with con, ply improved RE at 18 km.h⁻¹ (4.1%, p=0.002), but not at 14 or 16 km.h⁻¹. This was accompanied by trends for increased average power during a 5 jump plyometric test (15%) (p=0.11), a shorter time to reach maximal dynamic strength during a strength quality assessment test (14%, p=0.009) and a lower VO2 max speed slope (14%, p=0.12) after 9 weeks of ply. There were no significant differences in cardio respiratory measures or VO2 max as a result of ply. In a group of highly-trained distance runners, 9 weeks of ply improved RE, with likely mechanisms residing in the muscle, or alternatively by improving running mechanics.

Myer GD., et al, (2006). determined the effects of plyometric vs. dynamic stabilization and balance training on power, balance, and landing force in female athletes. Neuromuscular training protocols that include both plyometrics and dynamic balance exercises can significantly improve biomechanics and neuromuscular performance and reduce anterior cruciate ligament injury risk in female athletes. The purpose of this study was to compare the effects of plyometrics (PLYO) versus dynamic stabilization and balance training (BAL).
on power, balance, strength, and landing force in female athletes. Either PLYO or BAL were included as a component of a dynamic neuromuscular training regimen that reduced measures related to ACL injury and increased measures of performance. Nineteen high school female athletes participated in training 3 times a week for 7 weeks. The PLYO (n = 8) group did not receive any dynamic balance exercises and the BAL (n = 11) group did not receive any maximum effort jumps during training. Pre training vs. post training measures of impact force and standard deviation of center of pressure (COP) were recorded during a single leg hop and hold. Subjects were also tested for training effects in strength (isokinetic and isoinertial) and power (vertical jump). The percent change from pretest to posttest in vertical ground reaction force was significantly different between the BAL and PLYO groups on the dominant side (p < 0.05). Both groups decreased their standard deviation of center of pressure (COP) during hop landings in the medial/lateral direction on their dominant side, which equalized pretested side to side differences. Both groups increased hamstrings strength and vertical jump. The results of this study suggest that both PLYO and BAL training are effective at increasing measures of neuromuscular power and control. A combination of PLYO and
BAL training may further maximize the effectiveness of preseason training for female athletes.

Caputo F., and Denadai BS., (2004). conducted a study on effects of aerobic endurance training status and specificity on oxygen uptake kinetics during maximal exercise. The main purpose of this study was to analyze the effects of exercise mode, training status and specificity in the oxygen uptake (Vo$_2$ max) kinetics during maximal exercise performed in treadmill running and cycle ergometry. Seven runners (R), nine cyclists (C), nine triathletes (T) and eleven untrained subjects (U), performed the following tests on different days on a motorized treadmill and on a cycle ergometer. The U group showed the lowest values for VO2 max, regardless of exercise mode. Differences in tau Vo(2) (seconds) were found only for the U group in relation to the trained groups [R=31.6 (10.5) and 40.9 (13.6); C=28.5 (5.8) and 32.7 (5.7); t=32.5 (5.6) and 40.7 (7.5); U = 52.7 (8.5) and 62.2 (15.3). for the treadmill and cycle ergometer, respectively; no effects of exercise mode were found in any of the groups. It is concluded that tau VO(2max) during the exercise performed at VO(2max) is dependent on the training status, but not dependent on the exercise mode and specificity of training. Moreover, the transfer of the training effects on tau VO(2max)
between both exercise modes may be higher compared with VO(2max).

**Spurrs, Murphy and watsford., (2003).** Conducted a study to examine whether changes in running performance resulting from plyometric training were related to alterations in lower leg muscles tedious stillness (MTS). 17 male runners were pre and post-tested for lower leg MTS, maximum isometric force, rate of force development, 5-bound distance test (5BT), counter movement jump (CMJ) height, RE, Vo (2 max), lactate threshold [Th (cla)], and a 3-km time. The subjects were randomly split into an experimental (E) group which completed 6 weeks of plyometric training in conjunction with their normal running training, and a control(C) group which trained as normal. Following the training period, the E group significantly improved 3-km performance and RE at each of the tested velocities, while no changes in Vo (2 max) or Th (la) were recorded. CMJ height, 5 BT and MTS also increased significantly. No significant changes were observed in any measures for the C group. The result clearly demonstrated that a 6-week plyometric programme led to improvements in 3-km running performance. It is postulated that the increase in MTS resulted in improved RE which is believed to make changes in 3km running performance, as there were no corresponding alternations in Vo (2 max) or Th (la).
Millet GP., et al, (2002). Conducted a study on Effects of concurrent endurance and strength training on running economy and VO(2) kinetics. The purpose of this study was to examine the influence of a concurrent HWT+ endurance training on CR and the VO(2) kinetics in endurance athletes. Fifteen triathletes were assigned to endurance + strength (ES) or endurance – only (E) training for 14 wk. The training program was similar, except ES performed two HWT sessions a week. Before and after the training period, the subjects performed 1) and incremental field running test for determination of VO(2max) and the velocity associated (V(VO2max)), the second ventilatory threshold (VT(2)); 2) a 3000-m run at constant velocity, calculated to require 25% of the difference between VO(2max) and VT(2), to determine CR and the characteristics of the VO(2) kinetics; 3) maximal hopping tests to determine maximal mechanical power and lower-limb stiffness; 4) maximal concentric lower-limb strength measurements. Results showed that After the training period, maximal strength were increased (P<0.01) in ES but remained unchanged in E. Hopping power decreased in E(P<0.05). After training, economy (P<0.05) and hopping power (P<0.001) were greater in ES than in E. VO(2max), leg hoping stiffness and the VO(2) Kinetics were not significantly affected by training either in ES or E.
Diallo (2001). Examined the effectiveness of plyometric training and maintenance training on physical performances in prepubescent soccer on players was examined. Twenty boys aged 12-13 years were divided into two groups (10 in each): Jump group (JG) and control group (CG). JG trained 3 days/week during 10 weeks, and performed various plyometric exercises including jumping, hurdling and skipping. However, all subjects continued their soccer training. Maximal cycling power (P_max) was calculated using a force-velocity cycling test. Jumping power was assessed by using the following tests: counter movement jump (CMJ), squat jump (SJ), drop jump (DJ), multiple 5 bounds (MB5) and repeated rebound jump for 15 seconds (RRJ15). Running velocities included; 20, 30 and 40m (v20, v30, v40m). Body fat percentage (BF percent) and lean leg volume were estimated by anthropocentric before training; except for BF percent all baseline anthropometrics characteristics were similar between JG and CG. After the training program P_max, CMJ, SJ, MB5, RRJ15 and v20M, performances increased in the JG. During this period, no significant performance increase was obtained in the CG. After the 8 week of reduced training, except P_max for CG, any increase was observed in both groups. These results demonstrate that short-term plyometric training Programmes
increase athletic performances in prepubescent boys. These improvements were maintained after a period of reduced training.

2.4 SUMMARY OF THE LITERATURES

The review of literature helped the investigator to spot out relevant topics and variables. Further the literature help the investigator to frame the suitable plyometric training leading to the problems. The latest literature also helped the investigator to support him findings with regard to the problem. Further the literature collected in the study will also help the research scholar to have understanding in the similar areas. The reviews were presented under the three section such as plyometric training (n=13), Motor ability components, (n=25), and physiological variables (n=8) with chronological and alphabetical order. All the research studies were presented in the section proves that the plyometric training programme contribute significantly for better development of selected depended variables such as (Speed, leg explosive power, muscular endurance, Resting pulse rate, VO$_2$Max, Anaerobic power)